Health of Workers Exposed to Sodium Fluoride at Open Hearth Furnaces

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PUBLIC HEALTH BULLETIN NO. 299

Prepared by direction of the Surgeon General by J. WALTER HOUGH, *Medical Officer;* DOHRMAN H. BYERS, *Scientist;* VERNON J. FORNEY, *Dental Surgeon;* HUGH P. BRINTON, *Statistician;* ROBERT G. KEENAN, *Senior Assistant Scientist* (R); ROBERT P. RALLS, *Assistant Surgeon;* HAROLD J. PAULUS, *Senior Assistant Scientist* (R), from Industrial Hygiene Division, Bureau of State Services

Federal Security Agency • PUBLIC HEALTH SERVICE

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Contents

Abstract

Summary

The Industrial Hygiene Division of the Public Health Service was requested by representatives of the Republic Steel Corporation and the United Steelworkers of America, CIO, to make a study of the potential health hazards which might be associated with the use of sodium fluoride at open-hearth furnaces.

Field work was conducted from January 7 to February 8, 1948, in four Republic Steel Corp. plants in Ohio. Medical examinations were made of 350 males, including 24 Negroes, distributed as follows: One hundred and eighty-seven in two plants now using sodium fluoride, 63 in a plant where sodium fluoride formerly was used and 100 in a plant which had never used sodium fluoride.

The environmental study involved the collection of fume and gases in an electrostatic precipitator and standard impinger combined in series. A total of 149 air samples, 16 settled-dust samples and 9 control samples, were collected. Laboratory investigations included determinations of the following in the air: Fluorine, total fume, oxides of iron, and manganese. X-ray diffractions were made of fume and dust. Urine samples were studied to determine their fluorine content.

The medical study included a detailed occupational history, and a record of past diseases, operations, and injuries. Present symptoms were recorded with special emphasis on irritative effects of fume. A complete physical examination was performed with attention directed towards any evidence of lens opacity and inflammation of the mucous membranes of the eyes, nose, and throat. A 14- by 17-inch X-ray of the chest was taken of each worker as well as an X-ray of his left wrist and forearm. Urine was examined for albumin and sugar. Red and white blood cell counts, hemoglobin determinations, serologic tests for syphilis, and leucocyte differential counts were made from the blood of each individual.

A clinical oral examination was made of each employee. Procedures used in these examinations consisted of critical inspection of all oral

tissues and structures with the aid of two posterior bite-wing X-rays and lateral film of the lower left jaw.

Atmospheric concentrations of iron oxides, manganese, and total fume were similar in all four plants. The maximum concentrations of iron oxides and manganese were well within safe limits. The weighted exposures to total fume were rather low, although certain jobs involved high exposures of moderate duration. Sodium fluoride concentrations in the two plants using it were similar in magnitude and had overlapping ranges. With respect to both sodium fluoride and total fume, the cranemen had the greatest exposure and the pouring platform men were second. Weighted exposures to sodium fluoride for these two groups were 2.2 and 0.4 milligrams of sodium fluoride per cubic meter of air, and for all others they were negligible. Tar smoke and radiant heat were noted as discomforting factors in need of correction.

In the light of present information such concentrations of sodium fluoride would not be considered hazardous. However, brief exposures to the higher concentrations of total fume and dusts may irritate sensitive tissues of the nose, mouth, and throat.

No significant physical defects could be directly related to the use of sodium fluoride. Upper respiratory symptoms such as cough were also not related to exposure but on the contrary occurred most commonly in the control plant. These symptoms might be attributed to the total fume and dust content of the air in all plants. The laboratory and X-ray examinations did not reveal any condition which might be linked to the use of sodium fluoride. From these findings, it would appear that sodium fluoride does not constitute a health hazard under the conditions of this study.

Conclusions

1. Concentrations of iron oxides and manganese fumes were below the accepted maximum allowable concentrations and it is concluded that they would not constitute a significant health hazard.

2. When sodium fluoride was added to the molten steel in the molds or ladles, the compound was dispersed, without chemical change, into the working atmosphere. The weighted exposures of the workmen were not great enough, in the light of present information, to indicate any probable hazard or chronic toxic effects.

3. Acridine and other factors in the smoke from mold coatings, during coating and pouring operations, were very irritating.

4. Discomfort caused by radiant heat was excessive.

5. Fumes, smoke, and dust encountered at the open hearths induce an upper respiratory symptom complex which may be irritating and annoying.

6. According to the data on symptoms by plants, there is an inverse relationship of the symptomatology to the exposure to sodium fluoride.

7. No severe pharyngeal damage results from exposure to sodium fluoride. A slight degree of pharyngitis may possibly be caused by sodium fluoride, tar smoke, or sulfur dioxide fumes; it is difficult to separate the effects of these three environmental factors.

8. On a basis of physical and X-ray findings, there were no definite changes attributable to sodium fluoride.

9. Exposure to sodium fluoride has little or no disabling effect on the tissues and structures of the oral cavity. Sodium fluoride does not produce tissue necrosis when introduced into the oral cavity in atmospheric concentrations as experienced in the occupational environments which were investigated. However, sodium fluoride, in combination with other fumes and dusts, may be a contributing factor in producing soft-tissue inflammation in the mouth.

10. Repeated exposure to irritant factors in the occupational environment may produce increased thickening on vulnerable areas of the oral mucosae.

Recommendations

1. Mold-coating operations should be controlled to avoid unnecessarily thick coatings which result in considerable discomfort to workmen while pouring steel.

2. A mold-coating material giving less dense and less irritating smoke and fume than the present coatings should be sought.

3. Whenever possible intense exposure to radiant heat should be reduced or eliminated by use of protective clothing, remote controls, or other means.

4. The possibility of eliminating dust, fume, smoke, and heat exposures of cranemen, by the use of a positive-pressure ventilating system with filtering of intake air, should be explored.

5. Crane cab windows should be cleaned regularly and frequently to encourage the operators to keep these windows closed during peak exposure periods.

Origin of Study

The use of sodium fluoride in various industries throughout the country has mushroomed from pounds per day in 1942 to tons per day at the present time. Knowledge about its toxic properties in industrial processes, however, has not kept pace with its expanded utilization. Numerous questions concerning its effects on health have therefore arisen, particularly in connection with its use in open-hearth operations in steel mills.

Sodium fluoride is used in the manufacture of rimmed steel because it helps produce an ingot whose surface is free from blowholes and whose skin will withstand tearing and cracking. Its use preserves the fluid state of molten metal and prolongs solidification reaction time, thus allowing for the escape of trapped gases which would otherwise cause blowholes in the finished product.

Suspicion of potential health hazards inherent in the use of sodium fluoride has provoked much labor unrest. Workers have complained bitterly about its use.

To obtain conclusive information as to the existence of possible hazards, representatives of the Republic Steel Corp. and the United Steelworkers of America, CIO, requested the Industrial Hygiene Division of the Public Health Service to make a thorough study. Although surveys of the process had been made previously by other agencies, they had been confined to an investigation of the working environment and had not included medical and dental examinations of the workers involved.

The Public Health Service accordingly undertook a survey of the potential health hazards which might be associated with the use of sodium fluoride in open-hearth furnaces in four Republic Steel Corp. plants located in Ohio. This study was conducted between January 7 and February 8, 1948. The results of this investigation follow.

Environmental Findings

THE OPEN-HEARTH PROCESS FOR STEEL

As an introduction to the environmental phases of this study, a brief description of the open-hearth process and operations seems expedient. The presentation is intentionally short and general with possible excursions into details of particular interest. Only the pit-side environment was evaluated.

The making of steel is essentially the purification of pig iron and scrap. The open-hearth process is one method of accomplishing this through the burning-out of carbon and the incorporation and removal of other impurities in the slag. The open-hearth furnace is a large rectangular brick oven with a basin-shaped hearth. A series of vertically sliding doors at the front faces the charge floor from which the raw materials are fed to the furnace. Scrap iron, limestone and iron ore are weighed into charging pans in the stock house. The charging pans are brought by rail to the charge floor and their contents dumped into the furnace by means of a mechanical ram-type charger. Molten pig iron is poured directly into the open hearth. The gas or oil flame is then turned on and the charge is allowed to melt and work. Further additions of raw materials or alloying elements may be made from time to time. As the heat nears completion, tests are taken to the laboratory and the melter keeps an experienced eye on the furnace's contents. When the analysis and temperature are right for the desired type of steel, the heat is ready to be tapped. The cycle from charging to tapping requires from 10 to 14 hours.

The tap hole runs from the lowest point in the basin of the hearth out through the back of the furnace. When the steel is ready, a crew digs out the fire-clay plug and burns the hole open. The molten steel flows rapidly from the tap hole, along a runner and into a ladle located in the pit. Further addition of materials such as coal, sulfur, ferromanganese, aluminum, and sodium fluoride may be made to the steel in the ladle. Less frequently alloying elements such as chromium and vanadium may be thus added. Bags of the materials may be

790731—48——2

thrown into the ladle or the loose material shoveled in. The slag also flows into the ladle but it overflows thence into a slag thimble. When tapping is complete a ladle crane takes the ladleful of liquid steel away to be cast into ingots.

The pouring platforms, located across the pit from the back of the furnaces, are about on a level with the tops of the ingot molds. The molds set on buggies on a railway siding alongside the platform. The craneman maneuvers the ladle over each mold in succession while the steel pourer operates the stopper to control the flow of steel from the nozzle. As the steel is thus cast, additional chemicals such as aluminum and sodium fluoride may be added to each ingot. After the pour is completed, the ingots are hauled away to be stripped and eventually rolled.

The foregoing has not mentioned the numerous other activities of the charge floor and pit incidental to the actual making and casting of the steel. Each time a ladle has been used the skull of slag and steel residue must be removed and a new nozzle and stopper put in place. Periodically the slag and spill must be cleaned up. Most of these operations might be considered as routine maintenance. The charge floor men are responsible for keeping the furnaces in proper condition.

OCCUPATIONAL ANALYSIS AND DESCRIPTIONS

In the course of the study, it was found that job titles varied appreciably in their meaning from plant to plant. The same titles often referred to different jobs or a given job would be known by entirely different titles in the various plants. To prevent the confusion which could so easily occur in reporting on such a situation, the company was asked to provide a list of standard job titles and to correlate them to the job titles used in the individual plants. This information was used in the preparation of table 1.

All of the workers included in this study are classed into four broad occupational groups according to the location and nature of their work. Group 1 consists of the crane operators whose area of work is mobile but rather definitely defined by the limits of the crane cab. In group 2 are placed all men who work with any degree of regularity on the pouring platform during pouring operations. These men also spend considerable time in the pit. Men whose work is mostly confined to the pit comprise the third group. Into group 4 are assembled men who work in other locations and have limited exposures to the pit-side environment. An analysis by plant of the number of men in each occupation and broad grouping is given in table 2.

Table 1.—*Conversion of job titles in the open-hearth department of 4 steel plants*

Plant title as given on medical examination schedules	Standard titles			
	Plant A	Plant B	Plant C	Plant D
Ladle craneman	Ladle craneman	Ladle craneman	Ladle craneman	Ladle craneman.
Hot metal craneman	Hot metal craneman	Hot metal craneman	Hot metal craneman	Hot metal craneman.
First ladleman	Steel pourer	First ladleman	First ladleman	First ladleman.
Second ladleman	Platform man	Steel pourer	Steel pourer	Steel pourer.
Third ladleman	Helper, platform man	Helper, nozzle setter		Helper, ladleman.
Platform man		Platform man		
Steel pourer		(Steel pourer)		
Pit leader	First ladleman		(First ladleman)	(First ladleman).
Fourth ladleman	Helper, platform man	Helper, platform man		
Ladleman helper		(Ladleman helper)		
Nozzle setter		(Helper, nozzle setter)		
Nozzle setter helper		(Helper, nozzle setter)		
Pit floater	(Helper, nozzle setter)			
Pitman			Helper, nozzle setter	Pitman.
Pit laborer				Slagger.
Second helper	Second helper	Second helper	Second helper	Second helper.
Observer	Observer	Observer	Observer	Observer.
Ingot shipper	Pitman	Pitman		Pitman.
Mold shed worker				Mold shed worker.
Electric foreman	Turn foreman, electrical	Turn foreman, electrical	Turn foreman, electrical	Turn foreman, electrical.

Column 1 lists all of the job titles as given on the medical examination schedules for all men examined at the 4 plants.

Columns 2, 3, 4, and 5 list the standard job title corresponding to the plant titles in column 1 at each plant. The conversion of titles was made by reference to the "Correlation of job titles" table furnished by the company. Blanks occur where no workers by the titles in column 1 were listed at the corresponding plant. Titles in parentheses indicate that no correlation of such a plant title was given and the probable best standard title is thus indicated.

Table 2.—*Broad occupational grouping of male workers in the open-hearth department of 4 steel plants*

Occupation	Total	Plant A	Plant B	Plant C	Plant D
Total, all occupations	350	48	63	139	100
	Group 1—Cranemen				
Total	56	10	16	18	12
Ladle craneman	50	10	16	12	12
Hot metal craneman	6	0	0	6	0
	Group 2—Platform workers				
Total	80	26	18	20	16
First ladleman	31	4	5	12	10
Steel pourer	27	8	5	8	6
Platform man	9	4	5	0	0
Helper, platform man	13	10	3	0	0
	Group 3—Pit workers				
Total	125	6	22	40	57
Helper, nozzle setter	40	1	13	0	26
Ladleman helper	9	0	9	0	0
Slagger	0	0	0	0	0
Pitman	76	5	0	40	31
	Group 4—Tap, charge, and other workers				
Total	89	6	7	61	15
Observer	16	5	4	7	0
Stocker	1	1	0	0	0
Second helper	57	0	3	54	0
Turn foreman, electrical	2	0	0	0	2
Mold shed worker	13	0	0	0	13

The responsibilities, operations, and working areas for the various occupations are briefly given in the discussion which follows:

Ladle craneman.—This man operates the ladle crane for the lifting and moving of ladles, thimbles, pots, mud buckets, runners, stopper rods, and supplies. During pouring he maneuvers the ladle into position over each mold. He also assists in pit clean-up operations. He is responsible for inspecting his crane.

Hot metal craneman.—This man operates an overhead crane on the charge floor for the addition of molten pig iron to the furnaces and other heavy lifting operations in handling materials of the charge floor.

First ladleman.—He is responsible for the direction and supervision of the operations of a pit and pouring platform crew. The preparation of ladles, thimbles, bottom pours, the pouring operations and pit clean-up all come within his province. The degree of responsibility will vary with the size of the plant.

Steel pourer.—He assists the first ladleman in all pouring platform

operations and usually handles the stopper control during pouring. He will also do general work in the preparation of ladles and other pit operations.

Platform man.—The inspection of molds and bottom pour runners and the stocking of supplies for the pouring platform are duties of this man. During pouring he makes the mold additions of sodium fluoride or aluminum, takes test samples, uses the oxygen lance on

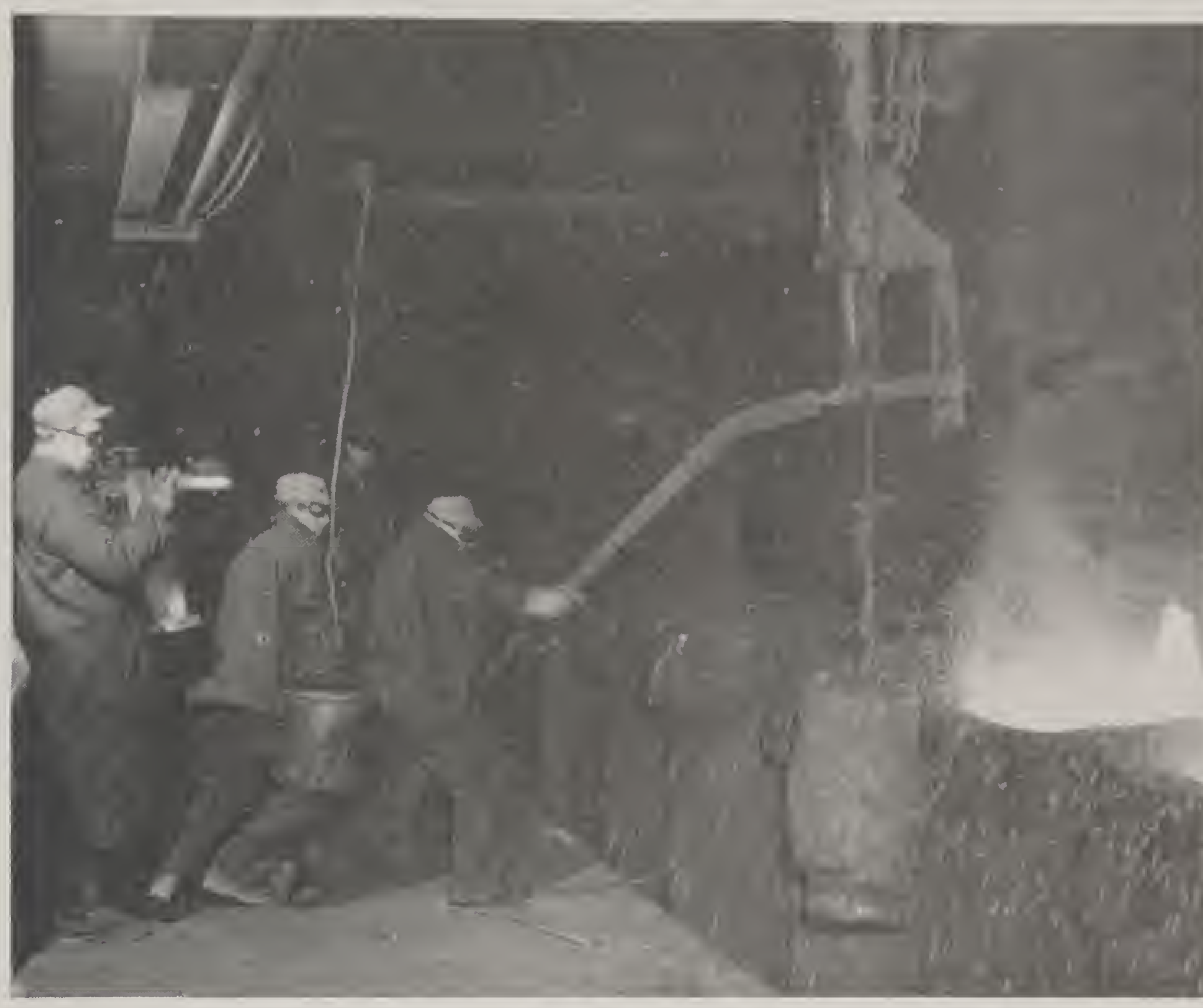

Figure 1.—*Operating the stopper for a shut-off during pouring of rimmed steel. At right steel may be seen pouring from the ladle into the mold. At the left an industrial hygiene engineer is taking an air sample with the combined sampler described in the text.*

frozen nozzles, and splashes slag from the ingot. He will also do general pit work.

Helper, platform man.—He assists the platform man in all operations as directed.

Helper, nozzle setter.—This man assists in the preparation of ladles; setting nozzles and stoppers, drying new linings and changing or moving flush pots. He helps the craneman in moving ladles, thimbles, and other items. He does general pit work and may help on the platform when necessary.

Ladleman helper.—The title is descriptive as his duties are to help in any way with the work of the first ladleman.

Slagger.—This title is applied to unskilled laborers engaged in clean-up and maintenance operations in the pit.

Pitman.—Engaged in general labor in the pit; this man is somewhat more experienced and skilled than the slagger.

Observer.—Preliminary tests for manganese and carbon content of the steel are made by the observer. His responsibility is to observe and write up the detailed information on each heat produced. As much as 15 percent of his time may be spent in the pit, but mostly he is on the charge floor.

Stocker.—Although his work is primarily to assist in the handling of materials in the stock house, this man may be called upon to work as a relief man in the open-hearth department. His exposure to pit fumes would be irregular, infrequent, and very difficult to determine or predict.

Second helper.—This man is essentially a charge floor workman, however, certain of his duties take him into the pit from 1 to 2 hours per turn. It is his job to mud, prepare, and set the tapping runners. He also opens the tap hole and makes the addition of materials to the ladle during the tapping of his furnace.

Turn foreman, electrical.—He supervises electrical services and repairs in the open-hearth department.

Mold shed worker.—This man assists in the preparation of molds for the casting of ingots. He does not work in the pit environment except as a substitute.

INSTRUMENTS AND METHODS

Air Sampling

When this study was undertaken the question arose as to whether any fluorides in the atmosphere would be in the form of a dust, a gas, or a fume. The standard impinger, the electrostatic precipitator, and a combination filter and scrubber had variously been used by other workers in previous studies of the problem.[1, 2] Therefore a preliminary series of samples was taken at one of the plants to determine, if possible, the nature of the contaminants and the best means of collection. The electrostatic precipitator was used at a sampling rate of 3 cubic feet per minute. The standard impinger was used at the usual rate of flow, 1 cubic foot per minute. Solutions used in the impinger were 10 percent $NaOH$, 10 percent H_2SO_4 and distilled water. As a

[1] Markuson, K. E.: The use of sodium fluoride in the manufacture of steel. *Ind. Med.,* 16 : 434, Sept. 1947.

[2] Unpublished data.

result of this work it was thought best to combine the two instruments for the collection of all air samples throughout the study.

A special holder was constructed to use a portable extension head of the electrostatic precipitator in series with an all-glass standard impinger, in that respective order. The connection between the precipitator head and the impinger tube was made by means of short lengths of aluminum and rubber tubing. The fit was such as to give a minimum exposure of rubber to the gases being drawn through the setup. The exhaust tube of the impinger was connected by 8 to 10 feet of rubber tubing to a Wilson pump, which furnished the source of suction. All samples were taken at the rate of 1 cubic foot per minute.

One hundred milliliters of 1 percent NaOH was used in the impinger. Phenolphthalein indicator was added to a few of the samples to demonstrate that the alkalinity of the solution was not being exhausted by any possible acid gases.

The aluminum precipitator collection tubes, used for all samples, were coated with a thin film of lucite (methyl methacrylate) to prevent any possible reaction of the aluminum with fluorine compounds in the sample. Laboratory tests showed that this coating did not introduce any significant error into the subsequent analyses.

The extension head allowed a moderate freedom of movement for 15 to 20 feet, however, frequent movements of the pump and electrostatic potential source were necessary to keep the sampling apparatus in the working area as the men moved along the extended pouring platform. The usual Wilson pump arrangement proved too clumsy to manage, therefore the motor and pump were mounted on a flat base with a sling handle so that a helper could move both pieces of equipment while the person taking the sample was allowed sufficient freedom to keep up with the workers. Due to voltage variations on the platform and the bitter cold weather encountered, it was necessary to use a one-sixth horsepower high-torque motor with the Wilson pump. The usual one-tenth horsepower hi-speed motor was not equal to the job of turning the pump at the required speed. Electric power was supplied from 110-volt alternating current outlets along the platform. Several hundred feet of extension cord were used so that there would be no interruption of the sampling operation over the entire length of the pouring platform. Every effort was made to move with the workers and take the samples in their actual breathing zones. Each sample represents the complete pouring of a ladle of steel.

In the crane cab the usual Wilson pump arrangement with a resistor was used on 250-volt direct current. The cabs were warm and the voltage ample for the small motors. The 110-volt alternating current for the electrostatic precipitator was obtained either by means of an extension cord from the platform or by the use of an inverter. These inverters changed 250-volt direct current to 110-volt, 60-cycle, alternating

current. They did not have sufficient capacity to operate the motor and pump but were excellent for use with the electrostatic precipitator. Samples in the crane cab were taken in the operator's breathing zone.

General air samples in the pit and on the tapping platform were taken on stationary mounts at selected positions. The sampling holder was designed so that it could be attached to a tripod.

Settled Dust

Samples of settled dust were taken from overhead and protected surfaces to eliminate, insofar as possible, general dirt. A steel spatula was used to remove the dust and place it in a sample envelope.

Chemical Methods

The fume and dust collected in the precipitator tubes was analyzed separately from the solutions contained in the impingers. The methods used differed only in the preliminary treatment of the two types of samples. Details of the analytical methods are given in the following paragraphs.

Determination of total fume.—The exterior surfaces of aluminum-collecting electrodes containing the fume samples were cleaned with redistilled 95 percent ethyl alcohol on a clean gauze pad, wiped dry with a second clean gauze pad and allowed to come to a state of equilibrium with the atmosphere for a period of 10 minutes (5 tubes were taken in each group). The tubes were then weighed directly on the pan of the Christian Becker, magnetically damped, analytical balance. The fume samples were then removed, with the use of either water or 30 percent alcohol and a rubber policeman, to platinum dishes. A wad of gauze was forced through the electrodes in order to remove all moisture, the outer surfaces were cleansed as previously and, after a 10-minute equilibrium period was again permitted to elapse, the tubes were reweighed. The differences in the electrode weighings, before and after sample removal, constituted the total fume weights.

Determination of fluorine.—A minimum of 2 milliliters of a 10 percent solution of Na_2CO_3 was added to each sample. A greater volume of this reagent was desirable in the heaviest samples—up to 7 milliliters were added. The sample was evaporated to dryness on the steam bath, ashed at 550° C. in the muffle furnace for 2 hours (if manganese was to be determined on the residue, otherwise ashing was replaced by boiling with 0.5–1.0 milliliter saturated $KMnO_4$ solution) cooled and transferred to the flask of the fluorine distillation apparatus with water and 1 N NaOH (using a policeman). Fifteen milliliters of 60 percent perchloric acid, reagent grade, were added, the temperature of the mixture was raised to 135–140° C. and the hydrofluosilicic acid was steam-distilled between 140–150° C., the distillate being received in a conical

beaker containing 5 milliliters of 1 N sodium hydroxide. About 150 milliliters of distillate were collected, the alkalinity was checked and then it was diluted to 250 milliliters in a volumetric flask and a suitable aliquot taken for either the colorimetric zirconium alizarin procedure or the thorium nitrate titrimetric method, depending upon the fluorine content of the sample. Generally, the titrimetric method was applied to a 50/250 aliquot portion of each sample; if a low result was obtained, a separate aliquot was carried through the colorimetric procedure.

Determination of manganese.—As noted above in the fluorine procedure, all samples to be analyzed subsequently for manganese were ashed prior to the fluorine steam-distillation procedure. Upon completion of this the still residue, containing metallic perchlorates, other salts and free perchloric acid, was transferred to 250-milliliter Phillips beakers followed by a thorough washing of the still with 10–15 milliliters of concentrated hydrochloric acid. These washings were added to the main portion and the resulting solution evaporated to dryness. Ten milliliters of 18 N sulfuric acid and 5 milliliters of concentrated nitric acid were added and the sample was evaporated to fumes of sulfur trioxide. The sample was then diluted with approximately 5 milliliters of water, the sides of the beaker being rinsed down at this time, and evaporation to sulfur trioxide fumes effected again. To the resulting solution were added 3 milliliters of orthophosphoric acid and 30 milliliters of water and the sample was heated for a few minutes. It was then boiled gently with 0.3 gram of potassium periodate until the full permanganate color was developed. Upon being cooled to room temperature, it was transferred to a graduated cylinder, made up to a volume of 75 milliliters and compared with standards which had been carried through the same procedure.

Determination of iron.—If fluoride had also been determined on the precipitator samples, the residue was washed from the distilling flask with water and 1:1 hydrochloric acid. This solution was evaporated to 30–40 milliliters and adjusted with 20 percent NaOH and dilute HCl until only slightly acid. After heating, the sample was poured rapidly with stirring into 50 milliliters of hot 10 percent NaOH. It was boiled gently for several minutes, and the precipitate was allowed to digest for a short while before cooling and filtering. The filter paper was wet with hot 5 percent NaOH containing a little Na_2SO_4 before filtering. The precipitate was washed thoroughly with hot water and the filtrate discarded. Ten to twenty milliliters of 6 N HCl was used to dissolve the precipitate into a 250-milliliter beaker. It was found necessary to put the paper in the beaker, add water and heat to obtain complete solution of the ferric hydroxide. The solution was refiltered to remove paper and insoluble material. Five milliliters of 1:1 H_2SO_4 was added and the sample evaporated to SO_3 fumes. Twice again the sample was taken to fumes of SO_3 after washing

down the walls of the beaker each time with a small quantity of water. On the third evaporation, it was allowed to fume strongly for several minutes, then cooled and diluted to 50 milliliters. This volume was passed through a Jones Reductor, followed by 75 milliliters of 5 percent H_2SO_4, and titrated with 0.01 N $KMnO_4$. Orthophenanthroline indicator was used.

On precipitator portions which were not analyzed for fluorine, the sample was washed into a platinum dish and evaporated to dryness. The residue was taken up in concentrated HCl and diluted to 100 milliliters. One-half of the sample was taken for the iron analysis. The aliquot was made just acid and treated by the same procedure as above.

Impinger samples.—All impinger samples had been collected in 1 percent sodium hydroxide. They were diluted to a volume of 200 or 250 milliliters, mixed thoroughly, and split into two portions—one for the fluorine determination and the other for manganese analysis.

The fluorine portion was transferred to a platinum dish and evaporated to dryness on the steam bath. It was then transferred to a fluorine still, 0.5 to 1.0 milliliter of a saturated solution of potassium permanganate was added and the mixture was boiled for 30 minutes in order to oxidize any organic material. After cooling, 15 milliliters of 60 percent perchloric acid were added and the hydrofluosilicic acid distilled as described under the fluorine procedure for precipitator samples.

The manganese portion was transferred to a conical beaker and acidified with 18 N sulfuric acid. Ten milliliters excess of this acid and 5 milliliters of concentrated nitric acid were then added and the solution was evaporated to fumes of sulfur trioxide. It was then diluted with an equal volume of water (by washing down the sides of the beaker), 2 milliliters of 6 N hydrochloric acid were added and the sample evaporated to sulfur trioxide fumes again. Water was added once more and after fuming as above, the sample was heated with 3 milliliters of orthophosphoric acid, 30 milliliters of water, and the permanganate color developed by boiling with potassium periodate as described under the manganese procedure for precipitator samples.

Urine samples.—Although the results of the analyses of urine specimens for fluorine are not presented in the environmental section of this report, the analyses were made in the same laboratory as the others and it seems most appropriate to describe the chemical procedure with the other methods.

Approximately 1 gram of calcium oxide and several milliliters of formalin were added to each urine specimen at the time of collection. The volume of each specimen was measured and the sample transferred to a platinum dish. After evaporating to dryness on a hot plate, the residue was ashed in a muffle furnace at 600° C. until a gray ash was

obtained. This ash was transferred with a minmum amount of water to the distilling flask. Five grams of silver perchlorate monohydrate in aqueous solution was added to precipitate the chlorides. Then perchloric acid was added and the distillation and determination carried out as previously described. The alkaline distillate was concentrated and a 50 percent aliquot used for the colorimetric determination.

RESULTS OF THE STUDY

Observations of the Environment

The pit side of the open-hearth building is relatively open to air movement even during the winter months, as during this study. Doorways for railway cars and trucks are always open at both ends of the building and at one or more places along the side. Sections of the sheet-metal siding may be removed for additional ventilation in hot weather. Some such sections are left off the year round. Air movement is relatively unrestricted. The heat from the furnaces and molten steel creates strong convection currents tending to carry fume and smoke out through the monitor roof. However, these currents are not entirely constant and are subject to considerable turbulence. Wind currents entering the several openings are likely to be much stronger than the convection currents resulting in rather unpredictable conditions of air movement.

These variations of direction and rate of air motion greatly influence localized concentrations of gases, smoke, and fumes during such operations as tapping and pouring. To such extent as was possible within the limited time spent at each plant, a variety of conditions was evaluated in all working areas. It is felt that the samples taken represent a reasonably accurate picture of conditions in each plant at the time of the study. No attempt is made to extrapolate exposures to other conditions of weather and season.

Considerable variation of working temperatures is experienced by the workmen. Most of the excessive heat is produced by radiation from the molten steel rather than from actual air temperatures. During tapping the workers on the tapping platform are subject to intense radiant heat as well as considerably elevated air temperatures. This is particularly true during the addition of coal to the molten steel in the ladle. These exposures are of relatively short duration. On the pouring platform, the workers are subjected to intense radiant heat from the tops of the recently cast ingots and the molten stream from the ladle. The platform man engaged in capping ingots must face and work in this area of great radiant energy. He must retreat at frequent intervals to a less exposed area for a brief respite. The crane-

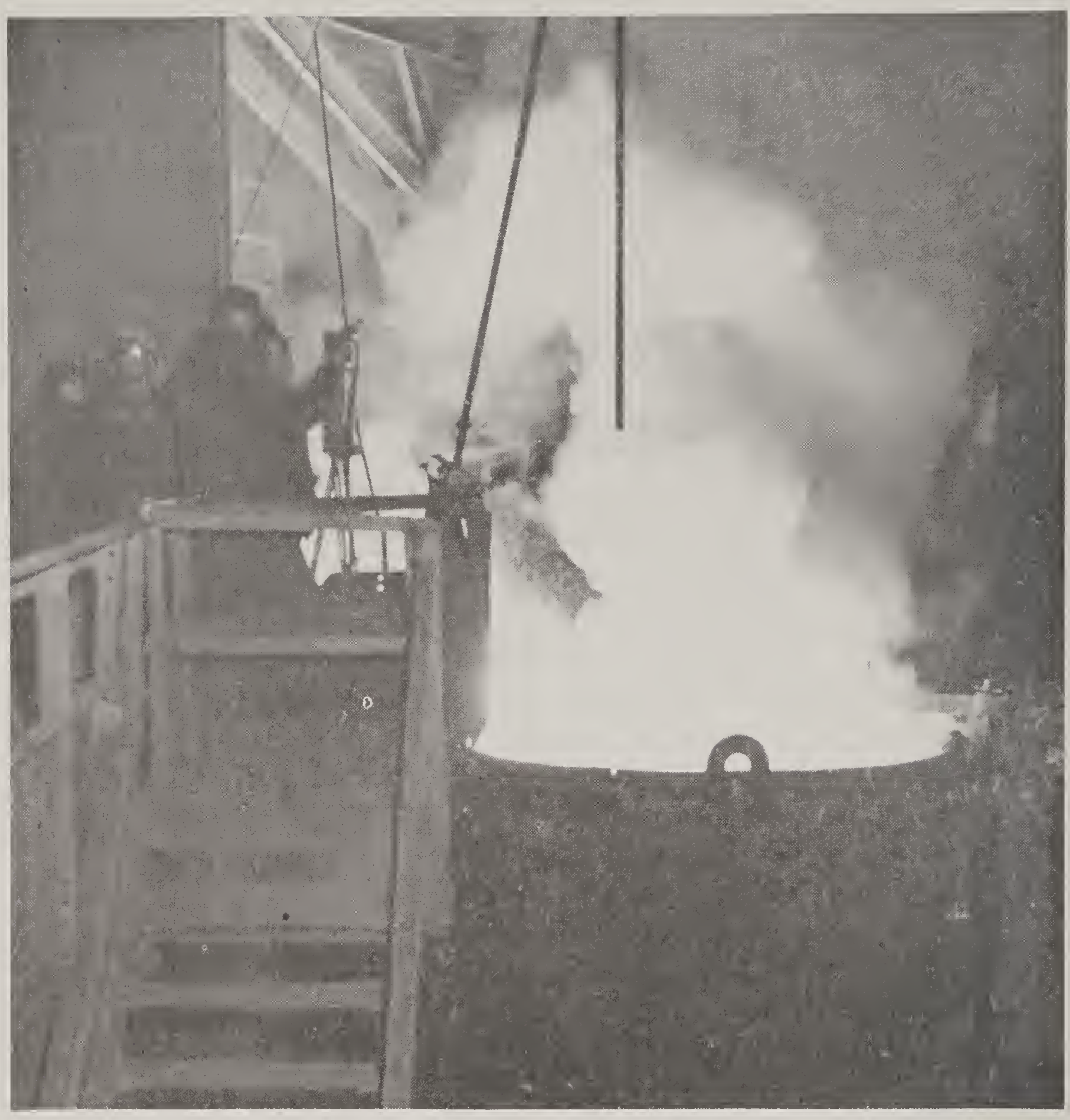

Figure 2.—*Air sampling on the tapping platform above the ladle during the tapping of an open-hearth furnace.*

man, the steel pourer, and the platform man making the mold additions are somewhat less exposed. When casting a double row of ingots all are uncomfortably exposed.

Inasmuch as this study was made in a period of uncommonly cold weather, the temperature extremes were particularly emphasized. This was especially true during the pouring. A cold wind will strike the men from one side while the other side is exposed to the radiation from the ingots and ladle. The men on the pouring platform are protected to some extent by the wool coats and protective leggings which they are required to wear. Except for the man handling the stopper lever, they have a certain degree of freedom to move about in order to escape the heat and fumes at intervals. The men in the pit experience the same to a lesser degree, whereas the tapping platform is relatively comfortable except during the actual tapping of an adjacent furnace.

Even then it is only necessary to move back far enough to be out of the line of the radiation.

For certain grades of steel the molds are coated with tar or pitch to ensure a better ingot surface. Plants A and C use a coal tar and plants B and D use purchased refined pitch. The former are also the plants which use sodium fluoride additions to rimmed steels. At plant A molds are coated by filling them with the molten tar and allowing them to drain. At the other three plants the coating materials are sprayed into the preheated molds. The spraying gives a relatively thin coating whereas at plant A many of the molds are apt to have a heavy coating and perhaps even a puddle of tar in the bottom of the mold. When molten steel pours into the molds the coating materials burn rather vigorously. With excessive amounts of tar in the mold the resulting flames may envelop the base of the ladle, perhaps enter the crane cab, and menace the workers on the platform. Considerable smoke and irritating fume are also evolved.

Qualitative tests of the tar smoke showed the presence of considerable amounts of acridine. Acridine is highly irritating to the mucosa. The smoke may also be presumed to contain anthracene and other such coal tar constituents. At plant A the mold yard is so located as to permit relatively concentrated clouds of the tar smoke to be blown into the pit-side working area. The workers complained considerably of this undesirable situation.

Ferromanganese, coal, sulfur, sodium fluoride, aluminum, etc., may be added to the steel in the ladle. The ferromanganese and aluminum produce no appreciable or obnoxious fume. Coal in 50-pound bags is thrown into the ladle. It burns intensely, producing large quantities of heat, smoke, and cinders which are thrown off into the surrounding working areas. Sulfur may be added in bags or shoveled in. Sulfur dioxide is evolved with the resulting characteristic irritating effects on all workers in the surrounding area. These sulfur heats are few in number and during this study only one sulfur heat was encountered.

Sodium fluoride is used in paper bags holding approximately 50 pounds each. Heretofore, the bags were filled by hand; however, this practice is being eliminated by purchasing the sodium fluoride already packaged in sealed bags. The required number of bags of sodium fluoride, usually two, are thrown into the ladle during tapping. Any resulting fume is not readily discernible from the other fume accompanying the tapping.

Sodium fluoride and aluminum may also be added to the steel in the molds to produce the proper rimming action. Aluminum shot is thrown in to kill excess action. Sodium fluoride in double, sealed, 4-ounce cellophane bags is added to increase the rimming action. The amount of either to be added to each mold is determined by the man

teeming the pour, and is dependent in part upon the carbon content and type of steel. The additions are made by throwing the materials into the molds as the steel is poured. At plant A two bags (8 ounces) are added to each mold of practically all of the rim heats, whereas at plant C from 15 to 20 bags (60 to 80 ounces) are added to each mold of many heats; smaller quantities being used on some heats.

The crane cabs are provided with electrical heaters which keep the interiors at a reasonably comfortable temperature even in the very cold weather. Pedestal fans are provided in most crane cabs to provide additional ventilation in the summer and to keep smoke and fume out by directing the air stream out the open window. The operators keep both windows open most of the time. Sometimes one window will be closed completely and the other partially during pouring operations. In general, the windows are too dirty to provide proper vision when closed. At plant C the ladle cranes each have a large fan mounted on the outside of the cab. These fans are so directed as to send an air stream away from the platform and between the molds and the cab window in an attempt to keep the fume and smoke from entering the cab.

The crane operators are subjected to some radiant heat but seldom for extended periods and usually of less intensity than on the platforms. While picking up a ladle of hot metal some radiant heat is received. During the pouring of molds in a single row, the crane operator is protected by the ladle between him and the hot ingots. In casting double lines of molds and occasionally in other activities the crane cab will be directly over hot or live ingots. Appreciable radiation can be received at such times. However, it is usually possible for the operator to shift his position so as to avoid the worst of these exposures. Past experience has proven it necessary to insulate the bottom of the cabs to prevent the metal floor plates from becoming too hot to stand on.

The men in the pit proper are the least subjected to smoke and fume from tapping and pouring operations. The convection currents tend to carry these upward away from the pit workers. They are exposed to a fair amount of radiant heat from hot molds, slag spills, etc. Usually excessively uncomfortable exposures are of brief duration or can be avoided by moving out of the immediate area.

The pit workers are exposed to high dust concentrations during the cleansing of slag from beneath the furnaces and spills from the pit floor. This dust is mostly slag, steel, and common dirt. There is no reason to suspect undue amounts of silica. Nevertheless the pit workers receive some exposure to silica during the relining of ladles and the rebuilding of furnaces. The environmental phase of this study did not concern itself with possible free silica exposures.

Settled-dust samples from the pouring platform, the tapping platform, and the crane cab were examined by X-ray diffraction. Magnetite, ferric oxide, and graphite were the principal constituents of the dusts. Quartz appeared in trace quantities in all of the samples. Only one of the samples showed amounts of sodium fluoride detectable by this method.

The dust and fume from an electrostatic precipitator sample taken over the mold while sodium fluoride was being added to the ingot showed a definite, strong X-ray diffraction pattern for sodium fluoride as such. The chemical analyses of the impinger portions of a number of air samples revealed relatively little fluorine in these solutions. The findings from these two approaches indicate that there was little, if any, formation of fluorine or hydrogen fluoride. It is probable that the fluoride contamination of the atmosphere is in the original form of sodium fluoride.

Iron and manganese were determined on a number of atmospheric dust and fume samples selected from all sampling locations and conditions at each of the four plants. The iron, expressed as ferric oxide, was found to range from 0.1 to 8.9 milligrams of ferric oxide per cubic meter of air. The manganese concentrations were very low with a maximum of 1.3 milligrams of manganese per cubic meter of air. In many of the samples manganese was not detectable by the method used. Even the maximum concentrations of iron and manganese found in these plants are well below the values at which any significant health impairment from these materials might be expected among the workers exposed.

The determination of iron and manganese served the very useful purpose of demonstrating that conditions in the several plants were comparable in respect to the concentrations of these substances in the air. There were no significant, distinguishable differences among the four plants upon the basis of these results. Iron forms approximately 99 percent of steel by weight and the percentages of manganese in the steels poured during this study did not vary greatly. These facts support the validity of using plants B and D, where sodium fluoride was not used, as controls for comparison with the other two plants in the evaluation of the possible health hazard from the fluoride exposures.

Table 3 offers in a brief form the results of the determinations of sodium fluoride concentrations in the pit-side atmosphere. In the upper portion of the table, concentrations found during the pouring of fluoride heats are grouped according to the working area in which the samples were taken. The values for the pouring platform include workers' exposures during pouring for all of the platform jobs. These

were all within the same range; therefore, they are grouped together. The general air samples were taken in the pit, on the tapping platform, on the crane escape platform, and in the cab of a crane not pouring at the time. These samples were collected while the pouring of fluoride heats was in progress but not in the immediate vicinity of the pouring. Those on the tapping platform were located directly across the pit from the pouring operation. The designation "tapping" refers to workers' exposures taken on the tapping platform during the tapping of a heat to which sodium fluoride was added in the ladle.

The lower portion of table 3 gives values for sodium fluoride concentrations during the pouring of heats to which no sodium fluoride was added in either the ladle or the molds. The first grouping is a composite of all such samples taken in the fluoride-using plants. This group includes both workers' exposures and general air. The values are all so very low as to have no significant difference with respect to exposure; therefore, they are presented as a single group representing the nonfluoride heat operations. The second grouping in this portion of the table shows the results of analyses for sodium fluoride in the air of the control plants, where the compound was not used. As might be assumed, no sodium fluoride was found.

Table 3.—*Concentrations of sodium fluoride in the air in various working areas in the open-hearth department of 4 steel plants*

[Concentrations expressed as milligrams sodium fluoride per cubic meter of air]

Working area	Number of samples	Concentrations: Minimum	Concentrations: Maximum	Concentrations: Median	Approximate duration of exposure, hours per day	Weighted daily exposure
	Heats using sodium fluoride					
Ladle crane	13	1.0	51.2	8.8	2	2.2
Pouring platform	29	.2	21.9	1.6	2	.4
General air	[1] 13	(2)	14.0	(2)	6–8	(2)
Tapping	[3] 4	(2)	40.1	1.0	1/3	(2)
	Heats not using sodium fluoride					
Composite of all areas in fluoride-using plants	[4] 21	(2)	0.3	(2)		(2)
Composite of all areas in nonfluoride-using plants	10	(2)	(2)	(2)		(2)

[1] Of these 13 samples, 8 showed negligible amounts of sodium fluoride and the remaining 5 showed values as follows: 0.2, 0.3, 0.4, 0.6, and 14.0.
[2] Negligible.
[3] These 4 samples had the following values: Negligible, 1.0, 1.1, 40.1.
[4] The only 3 positive samples in this group had values of 0.2, 0.3, and 0.3, respectively.

Because of the undue influence of a few very high values upon the arithmetical mean of such a limited number of samples, the mean is of dubious significance. It is felt that the median is a more repre-

sentative and valuable figure, hence it has been used in presenting the results and subsequent calculations. All values have been rounded off to the nearest tenth of a milligram and those below 0.05 milligram are indicated as negligible.

Total fume concentrations were determined upon the electrostatic precipitator portions of all atmospheric samples. This includes all particulate matter capable of collection under the conditions of sampling. Using the same grouping as to working area as in table 3, we have shown in table 4 the total fume concentrations found. The results for plants A and C were combined, as were those for plants B and D. The ranges were sufficiently close to recommend this approach. Under each working area there are three subdivisions. The samples taken during the tapping or pouring of fluoride heats have been separated from those representing activities in which sodium fluoride was not used, and the two sets of data shown separately. The third subdivision under each working area is the composite of all such samples from the control plants, which do not use sodium fluoride.

Table 4.—*Total fume concentrations by working areas in the open-hearth department of 4 steel plants*

[Concentrations expressed as milligrams total fume per cubic meter of air]

Working area	Condition	Number of samples	Concentration		
			Minimum	Maximum	Median
Ladle crane	Fluoride heats	13	2.8	73.4	14.8
	Nonfluoride heats	4	1.7	9.2	2.3
	Control plants	10	2.2	17.9	4.0
Pouring platform	Fluoride heats	29	.9	35.2	7.4
	Nonfluoride heats	3	2.4	3.1	3.0
	Control plants	16	1.6	10.7	3.4
General air	Fluoride heats	[1] 13	.9	34.8	4.1
	Nonfluoride heats	[2] 13	1.1	10.5	2.1
	Control plants	19	.3	24.8	4.0
Tapping	Fluoride addition	[3] 3	2.2	31.8	6.8
	No fluoride addition	2	3.5	7.8	(5.6)
	Control plants	2	2.1	5.7	(3.9)

[1] Three high values of this series were 34.8, 14.6, and 7.7.
[2] Three high values of this series were 10.5, 8.2, and 6.6.
[3] All 3 samples are shown. A fourth sample (595.0 mg./m^3) was discarded because of being so excessively out of line. It contained considerable coal dust and cinders of a large-particle size.

Of interest to note is the ratio of iron, as ferric oxide, to total fume. In all plants the ferric oxide was roughly 20–35 percent of the total fume. Although the relationship varied considerably, the majority of values fell into or near this range. At the control plants, the values tended to be somewhat higher. It is presumed that that portion of the total fume which is not accounted for as ferric oxide and sodium fluoride is tar smoke and general dust from the pit.

Previous mention has been made of the strong positive test for acridine in the tar smoke from the mold coating.

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Interpretation of Occupational Exposures

Concentrations of iron in the air, whether expressed as the element or one of the oxides, were not high enough to be considered as an important exposure with respect to possible health hazards. The same was true of manganese. For all plants the greatest iron concentration, expressed as ferric oxide, was 8.9 milligrams per cubic meter of air as compared with the generally accepted maximum allowable concentration of 15 milligrams of iron oxide fume per cubic meter of air.[3] Similarly for manganese the maximum concentration found was 1.3 milligrams of manganese per cubic meter in comparison with the usual limit of 6.0 milligrams.[3]

On the basis of an 8-hour workday, weighted exposures to sodium fluoride were calculated from the median values of the samples and from an estimate of the average hours per day spent in each exposure area.

For each occupation the weighted exposures were as follows:

OCCUPATION	*Milligrams of sodium fluoride per cubic meter of air*
Ladle craneman	2.2
Hot metal craneman	([1])
First ladleman	.4
Steel pourer	.4
Platform man	.4
Platform man helper	.4
Nozzle setter helper	([1])
Ladleman helper	([1])
Slagger	([1])
Pitman	([1])
Observer	([1])
Stocker	([1])
Second helper	([1])
Turn foreman, electrical	([1])
Mold shed worker	([1])

[1] Negligible.

The above figures thus obtained are indicative of the probable and comparative exposures of these occupations. The calculation of such exposure data is made extremely difficult by the intermittent and irregular schedule of operations. The number of heats poured in a shift by one platform crew may vary from none to five. Certain men work mostly in the pit and are on the pouring platform only when heats tap too close together for the regular pouring crew to handle them. It was possible to secure the total number of heats and the proportion of fluoride heats poured during the preceding year. From these data and the observed length of the operations an average

[3] 1947 M. A. C. Values (accepted by the American Conference of Governmental Industrial Hygienists) *Industrial Hygiene Newsletter*, August 1947.

was obtained for the time spent in pouring fluoride and nonfluoride heats by a crew in a turn. The task was made somewhat easier by the fact that all exposures on the pouring platform could be grouped together and that the exposures, other than during a fluoride pour, were generally negligible regardless of working area. Because of the relatively low value all pouring platform workers were given the same exposure value on the basis that none would vary significantly from this value. The crane operator's exposure was perhaps the easiest to estimate because he works his full turn in a definite area.

The weighted exposures are somewhat low with respect to previous thinking on the matter of threshold and permissible concentrations for sodium fluoride exposures. The actual exposures in the crane cab and on the pouring platform consist of several periods daily of 30 minutes to 1 hour in concentrations varying from low to quite high.

A further examination of table 4 will show that total fume concentrations are somewhat higher during the pouring of fluoride heats. An attempt to derive weighted exposure data in the same manner as was done with the sodium fluoride concentrations revealed no significant difference for the various occupations. Here also the exposure is a combination of high and low concentrations of varying duration. The weighted exposures range from 3 to 7 milligrams of total fume per cubic meter of air in plants A and C. The exposures at plants B and D tend somewhat toward the lower end of the range. At plant D the men complained of the smoke and fume from the electric furnaces located in the same building. Sampling was confined to the open-hearth areas and concentrations found were slightly, though hardly significantly, lower than in plant B. Any additional irritating effects attributable to the electric furnace fume would seem to be due to its chemical composition or to possibly more intense exposures in that department.

SUMMARY OF ENVIRONMENTAL FINDINGS

This report of the working environment on the pit side of open-hearth departments is based on conditions as found in four steel plants. Two of these plants used sodium fluoride and two did not. The study was made under winter weather conditions only. Included is an occupational analysis of the workers who were given physical examinations. This group included pit-side workers at the four plants and certain other selected groups.

Determination of iron oxide and manganese concentrations for the various locations and operations revealed that the maximum values were well below any which would be considered as dangerous to the

health of the employees. The uniformity of these results for all plants is noted as an index to the similarity of general, over-all conditions between those plants using sodium fluoride and those not using it.

The results of 90 determinations of sodium fluoride in the air are reported and the data are used to obtain a weighted exposure for the various occupations. The maximum and minimum exposure are widely spread for a given working area and the median is believed to be a more reliable index than the arithmetical mean. Concentrations of sodium fluoride are generally negligible except during and in the close vicinity of its use. The ladle crane operators receive the greatest exposures. The pouring platform workers receive a lesser exposure and other occupational exposures are negligible. Weighted exposures for the crane operators and pouring platform men are 2.2 and 0.4 milligrams of sodium fluoride per cubic meter of air, respectively. Exposures actually are intermittent and of moderate duration and cover a wide range of concentrations. Chemical and X-ray diffraction examinations of fume samples indicate that the sodium fluoride appears in the air unchanged.

Total fume concentrations are given. There is indication of greater total fume exposures with the use of sodium fluoride; however, weighted exposures for all occupations at the four plants fall into an approximate range of 3 to 7 milligrams of total fume per cubic meter of air.

Acridine is identified as a constituent of the smoke from the tar used for mold coating at plants A and C. At plant A the irritation from the tar smoke was particularly severe.

The discomfort arising from exposure to heat radiating from the molten steel and hot ingots is noted.

Results of the air samples show that the ladle-crane operators have the greatest exposure to sodium fluoride and total fume. They are also subject to heat, smoke, and occasionally even flames entering the cab windows during steel-pouring operations. The crane-cab windows are frequently, even usually, open during such operations.

CONCLUSIONS FROM ENVIRONMENTAL FINDINGS

1. Concentrations of iron oxides and manganese fumes were below the accepted maximum allowable concentrations and it is concluded that they would not constitute a significant health hazard.

2. When sodium fluoride was added to the molten steel in the molds or ladles, the compound was dispersed, without chemical change, into the working atmosphere. The weighted exposures of the workmen

were not great enough, in the light of present information, to indicate any probable hazard of chronic toxic effects.

3. Acridine and other irritating factors in the smoke from mold coatings, during coating and pouring operations, were very irritating to the sensitive tissue of the nose and throat.

4. Discomfort caused by radiant heat was excessive.

RECOMMENDATIONS FROM ENVIRONMENTAL FINDINGS

The following five recommendations are offered for the control or elimination of certain exposures noted in the environmental section of this report.

1. Mold-coating operations should be controlled to avoid unnecessarily thick coatings which result in considerable discomfort to workmen while pouring steel. The use of a dry spray of the coating material and proper preheating of the molds have proven effective at the plants using this method.

2. Substitution of a mold-coating material giving less dense and less irritating smoke and fume than the present coatings should be sought in order to eliminate the general discomfort and irritating effects to the cranemen and pouring crews. Research would be necessary to find such a material which would be also technically acceptable.

3. Wherever possible intense exposures to radiant heat should be reduced or eliminated by use of protective clothing, remote controls, or other means. On the tapping platform ladle additions should be made by remote-controlled, mechanical hoppers. Any device or change in procedure which will bring greater distance between the workman and the source of radiation would reduce the discomfort of the exposure.

4. The possibility of eliminating dust, fume, smoke, and heat exposures of cranemen by the use of a positive-pressure ventilating system with filtering of intake air should be explored.

5. Crane-cab windows should be cleaned regularly and frequently to permit proper vision when closed. This would encourage the operators to keep these windows closed during peak exposures to dusts, fumes, smoke, flame, and heat. These exposures could thus be materially reduced.

Characteristics of the Group Studied

AGE DISTRIBUTION OF WORKERS EXAMINED

As may be observed from table 5 the percentage age distribution of workers in the four plants studied shows a trend toward two distinct frequency curves reaching a peak at age 30 to 34 years and again at age 50 to 54 years. This appears unusual and suggests that two separate population groups may be involved. A fluoride-using plant and a plant that does not use fluoride show this peculiarity.

Table 5.—*Age distribution of male workers in the open-hearth department of 4 steel plants*

Age (years)	All plants	Plant A	Plant B	Plant C	Plant D
	Number				
Total	350	48	63	139	100
Under 25	20	0	1	11	8
25 to 29	34	3	5	21	5
30 to 34	55	6	11	28	10
35 to 39	44	5	7	25	7
40 to 44	37	14	5	7	11
45 to 49	46	12	11	8	15
50 to 54	55	3	15	17	20
55 to 59	36	3	4	14	15
60 to 64	13	1	3	4	5
65 or over	10	1	1	4	4
	Percent				
Total	100.0	100.0	100.0	100.0	100.0
Under 25	5.7	0	1.6	7.9	8.0
25 to 29	9.7	6.2	7.9	15.1	5.0
30 to 34	15.7	12.5	17.5	20.1	10.0
35 to 39	12.6	10.4	11.1	18.0	7.0
40 to 44	10.6	29.2	7.9	5.0	11.0
45 to 49	13.1	25.0	17.5	5.8	15.0
50 to 54	15.7	6.3	23.8	12.2	20.0
55 to 59	10.3	6.2	6.3	10.1	15.0
60 to 64	3.7	2.1	4.8	2.9	5.0
65 or over	2.9	2.1	1.6	2.9	4.0
Median age	43.0	43.6	46.1	36.9	48.0

[1] Public Health Bulletin No. 262.

A very much larger percentage of older workers were found in this study. For example, the percentage of males 50 years of age or over in certain industries is as follows: Open-hearth steel industry 32.6 (see table 5), storage battery industry[1] 18.1, Utah coal mines[2] 13.2, cemented tungsten carbide industry[3] 12.4, Utah metal mines[4] 12.0, shipyards[5] 11.1, asbestos industry[6] 5.4, and trucking industry[7] 1.2. The median age of open-hearth workers was 43 years. In none of the other industries cited above was a median age of 40 years reached and in 5 out of 7 industries the median was less than 35 years of age. The median age among males for plants in this study was 36.9, 43.6, 46.1, and 48.0 years.

BIRTHPLACE

Although open-hearth steelworkers remain for long periods within that same industry, there is considerable migration from one steel plant to another steel plant. This is evidenced by the fact that only 35.4 percent of these workers were residing in the State in which they were born at the time they were interviewed. Similar data for cemented tungsten carbide workers showed 67.2 percent working in the State where they were born. Even shipyard workers, who were considered a group with a high migration rate, had 38.7 percent working in the State where they were born. The percentages by individual open-hearth steel plants were as follows: 43.9, 37.5, 31.0, and 22.2.

The percentage of open-hearth workers born in the same or an adjacent State was 56.3 compared with 56.1 percent among shipyard workers. The percentages for the four open-hearth steel plants were 42.0, 44.4, 64.0, and 79.2. The chief reason for these considerable interplant differences appears to be the relative distance of a plant from the State boundary.

A third of all the workers examined in these plants were born in countries other than the United States. The percentage of foreign born among shipyard workers and cemented tungsten carbide workers was 4.7 percent and 11.9 percent, respectively. The two plants currently using sodium fluoride showed 16.7 and 30.2 percent of the workers to be foreign-born, while corresponding percentages for nonfluoride-using plants were 34.9 and 41.0.

Of the total foreign-born persons in the four plants seven-tenths were born in eastern Europe or Asia Minor, including Czechoslovakia,

[1] Public Health Bulletin No. 262.
[2] Public Health Bulletin No. 270.
[3] Unpublished data.
[4] Public Health Bulletin No. 277.
[5] Public Health Bulletin No. 298.
[6] Public Health Bulletin No. 241.
[7] Public Health Bulletin No. 265.

Yugoslavia, Hungary, Poland, Rumania, Serbia, Russia, Greece, and Turkey. Only 8 persons were born in the British Isles, 1 person each in Germany and Belgium, 14 persons in Italy, and 7 in Spain. One worker was born in Canada and none was born in Central or South America.

MARITAL STATUS

There was no large group of single men among these open-hearth steelworkers. Even among men under 30 years of age 57.4 percent were married. More than four-fifths of the men were married in each age group beginning with 30 to 34 years. The largest percentage married, 90.9, was in the age group 50 to 54 years. After this age the percentage married decreased because of an increase in the percentage of widowed, which reached a maximum of 8.7 percent among those 60 years of age or over. All of the widowed fell into the age groups 35 years of age or over. Those divorced were in the middle age groups, from 30 to 49 years.

Among open-hearth steelworkers the percentages married, single, or widowed or divorced were, respectively, 82.5, 12.6, and 4.9. Corresponding percentages for shipyard workers were 79.3, 16.3, and 4.4. Differences between the two groups are slight and due probably to the older age of the open-hearth steelworkers which tends to decrease the percentage single and increase the percentage widowed or divorced.

PERSONAL HABITS

Alcohol

The percentage of male open-hearth steelworkers who said they did not use alcohol was just one-half as great as among male shipyard workers; namely, 19.4 and 38.8 percent, respectively. However, in shipyards located in the North the percentage who did not use alcohol fell almost to the rate for open-hearth steelworkers, indicating that the difference may be principally related to regional factors. Among open-hearth steelworkers 30.7 percent said they used beer and wine only, 9.9 percent said they used liquor only, and 40.0 percent used all three types. Of those admitting to the use of alcohol in some form the percentage using all three types was almost the same for open-hearth steelworkers and shipyard workers.

The percentage of men who said they did not take alcohol in any form varied by plant as follows: 12.5, 15.9, 22.9, and 29.6. The higher percentages of total abstainers were in the two plants located in smaller

towns. In the two larger urban areas a greater percentage of the workers drank alcohol and a greater percentage drank all three types.

No age trends could be observed from table 6 in the percentage of persons taking alcohol.

Table 6.—*Percentage of male workers in the open-hearth department of 4 steel plants with certain habits, according to age*

Habits	Age (years)					
	Total	Under 30	30 to 39	40 to 49	50 to 59	60 or over
Use of tobacco:						
None	17.2	16.7	12.6	16.0	20.9	26.1
Smoking, with or without chewing	77.9	79.6	83.2	77.8	75.8	60.9
Chewing only	4.9	3.7	4.2	6.2	3.3	13.0
Use of alcohol:						
None	19.4	18.5	15.6	25.9	17.6	21.8
Beer and wine only	30.7	40.7	19.8	28.3	29.7	30.4
Liquor	49.9	40.8	64.6	35.8	52.7	47.8
Hours of sleep:						
6 or less	12.9	7.5	11.6	9.9	18.0	21.7
7 and 8	64.8	60.4	66.3	76.5	58.4	52.2
9 or over	22.3	32.1	22.1	13.6	23.6	26.1
Baths taken per week:						
Daily	26.5	38.9	36.5	22.5	16.7	8.7
6 to 3	49.6	51.8	58.3	52.5	38.9	39.1
2 or less	23.9	9.3	5.2	25.0	44.4	52.2

Tobacco

The use of tobacco was reported by 82.8 percent of the male open-hearth workers and 82.3 percent of the male shipyard workers. This remarkably close agreement in the use of tobacco compared with the difference in the use of alcohol suggests possible difficulties in eliciting a truthful response with respect to the latter habit. In most instances smoking, either alone or in combination with other forms of tobacco, was the type of use specified. Chewing tobacco or snuff only was reported by 4.9 percent of all workers. This was not evenly distributed because in one plant there was no report of this practice, and in the other three plants 4.1 percent, 5.2 percent, and 12.5 percent chewed or took snuff only.

According to age the percentage of open-hearth workers using tobacco was as follows: Less than 40 years 86.3 percent, 40 to 49 years 84.0 percent, 50 to 59 years 79.1 percent, and 60 years or over 73.9 percent. (See table 6.) As might be expected, persons who chewed or took snuff only were for the most part middle-aged or older.

Sleep

The percentage distribution of hours of sleep as reported by open-hearth workers was as follows: 5 hours or less 3.2 percent, 6 hours 9.7 percent, 7 hours 20.8 percent, 8 hours 44.0 percent, 9 hours 11.2

percent, and 10 hours or longer 11.1 percent. Compared with other groups for whom such information is available these workers slept longer than either shipyard workers or cemented tungsten carbide workers. For example, 22.3 percent of them slept 9 hours or longer while the other two groups showed 12.6 percent and 7.9 percent, respectively. They show almost identical percentages with shipyard workers when 8 hours and 5 hours or less of sleep are considered.

Certain trends with respect to age and hours of sleep were observed in table 6. The percentage of open-hearth steelworkers with 6 hours or less sleep was 7.5 under 30 years of age, 11.6 30 to 39 years, 9.9 40 to 49 years, 18.0 50 to 59 years, and 21.7 for 60 years or over. On the other hand, the percentage with 9 hours or longer sleep for the corresponding ages was 32.1, 22.1, 13.6, 23.6, and 26.1, respectively. From these data it would appear that the proportion of persons with a minimum amount of sleep tends to increase after 50 years of age, but the proportion of persons with the greatest amount of sleep appears high both in youth and old age. Plant differences in amount of sleep are considerable. The two plants in large cities showed a smaller proportion of men with 6 hours or less sleep and a higher proportion with 9 hours or more sleep than did the two plants located in the smaller cities. Possibly this may be related to the time consumed in going to and from work and tasks performed at home. Persons spending less time in travel would have more time for sleep.

Baths

Work in steel mills is extremely dirty so that frequent baths might be considered necessary. On the other hand, the present study was conducted during the middle of the winter at a time when the temperature was often below zero. Frequent bathing in such severe winter weather is unlikely. Daily baths were reported by 26.5 percent of the open-hearth steelworkers as compared with 23.8 percent of the cemented tungsten carbide workers and 47.0 percent of the shipyard workers. Almost half of the second group were examined during the summer and nearly all of the last group were examined when the temperature was above freezing. Taking the above facts into consideration, it would appear that open-hearth steelworkers made a relatively favorable showing with regard to daily baths. More than four baths per week were taken by 52.8 percent of these workers and by 34.8 percent of the cemented tungsten carbide workers. For the same industrial groups the percentage with two baths or less per week was 23.9 and 27.4.

There appears to be a definite inverse relationship between frequency of bathing and age as shown by table 6. The following percentage taking daily baths was observed: Under 30 years of age 38.9, 30 to 39

years of age 36.5, 40 to 49 years of age 22.5, 50 to 59 years of age 16.7, and 60 years of age or older 8.7. On the other hand, the percentage taking two baths or less per week in these age groups was as follows: 9.3, 5.2, 25.0, 44.4, and 52.2. In both series the trend toward less frequent baths with older age is noticeable.

WORK EXPERIENCE

Previous Occupational History

Because of a long history of employment in the steel industry the average worker examined in this study had other work experience of relatively short duration. No previous experience other than agriculture, forestry, or fishing was reported by 20.6 percent of the open-hearth workers, compared with 15.2 percent of the cemented tungsten carbide workers and 16.9 percent of the shipyard workers. Trade or service, with or without agricultural experience, was reported for 30.9 percent of the open-hearth workers. Dusty trades accounted for the past experience of 19.8 percent of the males examined. This was composed of mining and quarrying 9.4 percent, foundry work 5.2 percent, and other dusty trades including glass manufacture, brick making, and pottery making 5.2 percent.

The highest and lowest percentage of persons with previous experience in dusty trades, 31.3 percent and 13.0 percent, were found in the plants using sodium fluoride. No great interplant differences were observed (see appendix, table A) in the percentage of persons with no occupation other than agricultural work.

Experience in the Steel Industry

Early entrance and long-continued work within the industry is the characteristic pattern observed among open-hearth steelworkers. The men in these plants are no exception. Table 7 shows that 3.7 percent of the men examined had worked in the steel industry 40 years or over, 17.4 percent 30 years or over, 39.1 percent 20 years or over, and 64.8 percent 10 years or over. Mining is also an industry where employment is likely to be long continued, but Utah coal miners and Utah metal miners showed only 23.5 percent and 14.4 percent, respectively, who had worked 20 years or over, which is a considerably smaller proportion for this duration than found among open-hearth steelworkers. The largest percentage of workers with experience in steel ranging from 30 to 40 years was in plant B. Plant A had the largest group with 20 to 30 years' experience and plant C had the largest group with 10 to 20 years in steel. One plant using sodium fluoride had the largest percentage of workers with less than 10 years

in steel while the other plant using this material had the smallest percentage in this duration group. Each plant had more than one-fourth the workers with service of 20 years or over.

Table 7.—*Years worked in the steel industry by male employees in the open-hearth department of 4 steel plants*

Years in steel industry	All plants	Plant A	Plant B	Plant C	Plant D
	Number				
Total	350	48	63	139	100
Less than 5	56	3	12	23	18
5 to 9	67	6	9	32	20
10 to 14	49	5	6	30	8
15 to 19	41	8	8	14	11
20 to 24	42	10	7	10	15
25 to 29	34	10	5	7	12
30 to 34	30	4	9	8	9
35 to 39	18	1	5	8	4
40 to 44	12	1	2	6	3
45 to 49	1	0	0	1	0
	Percent				
Total	100.0	100.0	100.0	100.0	100.0
Less than 5	16.0	6.3	19.1	16.5	18.0
5 to 9	19.2	12.5	14.3	23.0	20.0
10 to 14	14.0	10.4	9.5	21.6	8.0
15 to 19	11.7	16.7	12.7	10.1	11.0
20 to 24	12.0	20.8	11.1	7.2	15.0
25 to 29	9.7	20.8	7.9	5.0	12.0
30 to 34	8.6	8.3	14.3	5.8	9.0
35 to 39	5.1	2.1	7.9	5.8	4.0
40 to 44	3.4	2.1	3.2	4.3	3.0
45 to 49	.3	0	0	.7	0

Of particular interest in the present study is the length of time workers had been in the open-hearth department of a steel plant. Although slightly more than half had been in that department less than 10 years, 20.3 percent had been in the same location 20 years or over and 5.5 percent had had open-hearth experience of 30 years or over.

Medical Findings

INTRODUCTION

Fluorides are regarded as general protoplasmic poisons, but their effect is altered according to the chemical compounds and amounts involved in the specific exposure. Thus, we see that gaseous fluorides, such as hydrogen fluoride and silicon tetrafluoride, are very toxic because of their solubility and reactivity. The undissociated hydrogen fluoride molecule is capable of penetration of the intact skin and may exert a systemic effect, as well as its corrosive local action.[1]

Cryolite (Na_3AlF_6) on the other end of the solubility scale has a low toxicity, as do the other almost insoluble fluorides. Since these compounds are not very irritating they are inhaled in large amounts without causing much cough and slowly absorbed to produce chronic poisoning or fluorosis. Outstanding symptoms of fluorosis are anorexia, vomiting, constipation, dyspnea on exertion, and rheumatic pains.

The bones usually develop osteosclerosis. There is an abnormal calcification of the tendinous muscle attachments, ligaments, and also marked periosteal bone formation. Drinking water which contained up to 3 parts per million did not cause skeletal sclerosis even in people who had been drinking it for a long time.[2] These changes may be the cause of some of the rheumatic-like pains. It has been estimated that 0.1 milligram of fluorine per kilogram of body weight daily may cause dental changes in children, and 0.20 to 0.35 milligram of fluorine per kilogram of body weight may cause bone changes after several years of exposure.[3]

Solutions of hydrogen fluoride and hydrofluosilicic acid are extremely toxic while relatively easily soluble fluorides and fluosilicates are classified as having high toxicity. Sodium fluoride falls in this latter group which is intermediate in the toxicity scale. Local corrosion is most pronounced from the extremely toxic group but may also

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[1] Roholm, Kaj: Flourine Intoxication. H. K. Lewis, London, 1937.

[2] Hodges, P. C.; Fareed, O. J.; Ruggy, George; and Chudnoff, J. S.: Skeletal sclerosis and chronic sodium fluoride poisoning. *J. Am. Med. Assoc.*, 117: 1938, Dec. 6, 1941.

[3] Roholm, Kaj: Flourine Intoxication. H. K. Lewis, London, 1937.

occur from sodium fluoride. Skin changes range from erythema to coriaceous changes which may progress to ulcers. Blisters and pustules are fairly common and loosened finger nails are said to occur. Irritation of the mucous membranes also occurs and results in sneezing, coughing, and chemical bronchitis. Hydrogen fluoride has been shown to be a harmful agent as a pulmonary irritant and volatile poison.[4] Outstanding in the experimental phase is the work done by McClure et al.,[5] who showed that up to 4 to 5 milligrams of sodium fluoride can be excreted daily without storage or harmful effects.

Other work indicates that inhaled fluorides are effectively absorbed. When absorption is great, a certain amount of storage occurs. Within limits, urinary excretion may be used as a measure of fluoride storage since the magnitude of urinary fluoride excretion varies directly with the amount absorbed.[6]

Acute poisoning from sodium fluoride is not of industrial importance and occurs almost entirely from accidental or intentional ingestion. A lethal dose varies from 5 to 15 grams when taken by mouth. It produces a hemorrhagic enteritis which progresses to death from shock. Small amounts of sodium fluoride may be swallowed by industrial workers and may cause anorexia, nausea, and vomiting.

Workers in the open-hearth department are also exposed to intensive heat and radiant energy from molten steel, and various gases from the pitch which lines the ingots. There were no heat effects anticipated as the study was done during the winter.

Radiant energy has long been suspected as a cause of cataracts. Most authorities believe that the infrared rays are the etiological factor although some still suspect ultraviolet.[7] Large exposures of infrared have been used experimentally to produce cataracts.

J. J. Johnstone describes the typical ray cataract as a fairly dense discrete posterior polar cataract. Slit lamp examination, as well as ophthalmoscopic, is necessary to establish the diagnosis. An attempt was made in this study to record all changes in lens opacity so that comparison may be made with other industrial groups. In this manner beginning changes can be estimated.

The fumes which come from the tar or pitch ingot lining contain a large amount of acridine. Impure acridine causes burning and itching of the mucous membranes which results in a violent sneeze or cough.[8]

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[4] Machle, Willard, and Kitzmillar, Karl: The effects of the inhalation of hydrogen fluoride. II. The response following exposure to low concentration. *Jour. Ind. Hyg. & Toxicol.,* 17: 223, Sept. 1935.

[5] McClure, F. J.; Mitchell, H. H.; Hamilton, T. S.; and Kinser, C. A.: Balances of fluorine ingested from various sources in food and water by five young men. *Jour. Ind. Hyg. & Toxicol.,* 27: 159, June 1945.

[6] Machle, Willard, and Largent, E. J.: Absorption and excretion of fluoride. *Jour. Ind. Hyg. & Toxicol.,* 25: 112, March 1943.

[7] Johnstone, J. J.: Heat ray cataract. *Tr. Ophth. Soc. United Kingdom,* 64: 252, 1945.

[8] Schwartz, Louis; Tulipan, Louis; and Peck, S. M.: Occupational Diseases of the Skin. Lea and Febiger, Philadelphia, 1947. P. 227, Acridine.

It may produce erythema and even swelling of the membranes of the eyes, nose, and throat. Its effect in this regard is very easily confused with that of sodium fluoride. Acridine may sensitize the skin to sunlight and may thus result in dermatitis.[9]

In some preparations of steel, elemental sulfur is introduced into the molten steel resulting in the evolution of irritating sulfur dioxide fumes. These fumes may also cause irritation of the nose and throat, producing cough and simulating the syndrome of other irritating gases.

PROCEDURES

History and Physical Examination

The medical study was made as complete as possible in an attempt to uncover possible health hazards. The worker's history included a detailed occupational record and a review of past history of disease. Present symptoms were elicited with special emphasis on the effects of fume irritation and suggestions of fluorosis.

Physical examination was quite complete with special emphasis on slight lens opacity and inflammation of the mucous membranes of the eyes, nose, and throat. Bony structure and function was checked.

Every worker had a chest X-ray, as well as an X-ray of his left wrist and forearm which included the elbow. The X-ray of the long bones was taken to determine whether abnormal changes were present.

Laboratory Tests

A. *Urine*

Urine specimens were collected from each person examined and studied for the following:

1. *Appearance.*—Determined by shaking and observing.
2. *Specific gravity.*—Determined by Squibb urinometer.
3. *Albumin.*—Determined by heat and acetic acid test.
4. *Glycosuria.*—Determined by Benedict's qualitative test.
5. *Microscopic.*—A microscopic examination was done only on urines exhibiting positive albumin.
6. *Chemical analysis.*—The urine remaining after the clinical analysis was placed in 8-ounce bottles, labeled with patient's number, occupation, and date, and analyzed for fluorides. One gram of calcium oxide to fix the fluorides and 2 cubic centimeters of formalin, to act as a preservative, were added.

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[9] Sollmann, Torald: Manual of Pharmacology. 7th ed., W. B. Saunders and Co., Philadelphia, 1948.

B. *Blood*

1. *Red blood cell count.*—Blood from finger prick was counted by the standard method.

2. *White blood cell count.*—Blood from finger prick was counted by the standard method.

3. *Hemoglobin.*—Hemoglobin was determined by a Haden-Hausser clinical model hemoglobinometer.

4. *Differential.*—A blood smear was made, stained by Wright's method, and differential count made.

5. *Serology.*—Blood was obtained by venipuncture and serological test for syphilis was done by the State health department.

6. *Sedimentation rate.*—Done by Wintrobe method using venous blood.

7. *Hematocrit.*—Done by using venous blood.

DISPENSARY VISITS

Each of the plants included in this study had a completely equipped dispensary where occupational injuries and occupational diseases were treated. The first time anyone came to the dispensary with a particular complaint a card was filled out and all subsequent treatments for the same complaint were entered on this card. From these records it was possible to learn the number of first visits made during the calendar year 1947 by each of the men who were given the physical examination by the Public Health Service. The two plants using sodium fluoride showed 43.7 and 26.6 percent of the men with no visits to the dispensary during the year, while the other two plants showed 63.5 and 29.0 percent. Exposure, age, and occupational rates cannot be compared for all plants taken as a whole because of the extreme interplant differences. The level of dispensary visits in a particular plant is apparently more closely related to local attitudes toward attendance than to the occurrence of minor injuries.

In general more frequent dispensary visits were found among the younger men and among those with relatively short experience in the open-hearth department. For example, 33.7 percent of all men with less than 5 years in the open-hearth department had five or more dispensary visits during 1947. Only 7 percent of the men with 20 years or more of experience had this many visits. Again, 50 percent of the men under 25 years of age had five or more visits compared with 3.4 percent of the men 55 years of age or over.

According to occupation cranemen had the fewest dispensary visits. Seventy-five percent had no visits to the dispensary, 12.5 percent had one visit, 7.1 percent had two visits, and 5.4 percent had three visits. No crane operators had more than three visits. The percentage

of persons with five or more visits was 12.4 for platform workers, 20.0 percent for pit workers, and 26.9 percent for tap, charge, and other workers. Considering the four plants separately the occupational group with the smallest percentage having no visits was pit workers in three plants and platform workers in one plant.

Dispensary visits and sodium fluoride exposure did not appear to be related. Moreover, in each of the plants using sodium fluoride the group of workers with the highest exposure showed the largest percentage of men with no or only one dispensary visit.

Occupational injuries or diseases were the reason given for 56.5 percent of the dispensary visits in plant A, for 83.8 percent of the visits in plant B, for 96.6 percent of the visits in plant C, and 80.1 percent of the visits in plant D. Occupational diseases were recorded in only one plant, amounting to 3.7 percent of all dispensary visits in that plant. One-third of these were said to be heat cramps and two-thirds were attributed to carbon monoxide gas from the furnaces. None was linked with sodium fluoride although this plant used the highest concentrations of sodium fluoride. The nonoccupational cases treated in the various plant dispensaries were obviously not connected with occupational exposure. They included for the most part injuries received at home or on the way to work and a few cases of colds or influenza.

SICK ABSENCES

Information was secured regarding sickness and nonindustrial injuries causing disability lasting 8 calendar days or longer for male open-hearth workers examined in the four steel plants. When results from the present study are compared with those from other plants it must be remembered that persons who were sick at the time of the medical examination were not included. This would tend to artificially lower these rates. The average annual number of cases of sickness and nonindustrial injury per 1,000 males was 69.7 for all ages, ranging from 61.1 in plant C to 84.2 in plant D. This may be compared with a rate of 79.8 in another large steel company reporting to the Public Health Service. Persons under 45 years of age had a frequency rate of 84.6 while persons 45 years of age or over had a rate of 60.0. The average annual number of days of disability per person was 1.77 for all males; for the younger age group it was 2.02 and for the older age group it was 1.61. The average number of days per case were 25.3, 23.8, and 26.7, respectively.

The diagnoses reported fail to indicate an above-average frequency of any particular disease. Comparison with the other steel company

mentioned above shows the following annual frequency rates per 1,000 males by cause:

Diagnosis	This study	Other steel company
All diagnoses	69. 7	79. 8
Nonindustrial injuries	12. 1	9. 4
Sickness	57. 6	70. 4
Respiratory disease	15. 2	24. 1
Digestive disease	9. 1	12. 6
Nonrespiratory-nondigestive disease	33. 3	33. 7

It appears that the present company had a less favorable experience with nonindustrial injuries, but a decidedly more favorable experience with respiratory diseases, and a somewhat more favorable experience with digestive diseases. Nonrespiratory-nondigestive diseases occurred with almost the same frequency. The 11 cases grouped under nonrespiratory-nondigestive diseases included the following: Diseases of the circulatory system two cases, genitourinary diseases one case, rheumatic disease three cases, diseases of the sense organs two cases, and diseases of the skin three cases. There was no appreciable difference in the type of case reported by the fluoride-using and the nonfluoride-using plants.

The frequency of sickness and nonindustrial injuries per 1,000 males according to occupation was 90.9 for cranemen, 69.6 for pit workers, 64.9 for platform workers, and 60.2 for tap, charge, and other workers. A break-down by plant shows that the high rate for cranemen is produced by the experience of the one plant which never had used sodium fluoride. In the two plants using sodium fluoride no cranemen had been absent 8 days or longer because of sickness or nonindustrial injury.

PREVIOUS ILLNESSES

Open-hearth workers were questioned whether they had ever suffered from certain types of illnesses. The types selected were such that reasonably accurate answers could be expected from the persons giving the information. Attacks of illness recalled were as follows: Pneumonia 12.9 percent, rheumatism 12.6 percent, skin trouble 12.3 percent, and asthma 2.0 percent. Comparable percentages for cemented tungsten carbide workers were 17.3, 21.9, 30.8, and 4.8. In every instance the latter group of workers had a substantially higher percentage with attacks reported than did open-hearth workers. Shipyard

workers showed larger percentages for pneumonia, rheumatism, and asthma, but a lower percentage for skin trouble. Considering the long time which these men had worked in the steel industry and in the open-hearth department their occupation has not apparently led to an excess of pneumonia. Tuberculosis was reported by one open-hearth worker (0.3 percent) although in each of the two other industries mentioned above it was named by 1.2 percent.

The two plants using sodium fluoride had lower percentages reporting pneumonia than the other plants, namely 8.6 and 12.5 percent compared with 14.3 and 18.0 percent. The percentage of workers who had had skin trouble did not vary greatly, being 14.6 and 12.9 in the fluoride-using plants and 12.0 and 9.5 percent in the other plants. Similar percentages for rheumatism were 10.8 and 12.5 percent compared with 18.0 and 7.9 percent. The percentage of workers who reported one or more colds during the previous year was less in the fluoride-using plants: 33.3 and 29.7 percent, while the other plants reported 45.9 and 43.9 percent.

HISTORY AND SYMPTOMS

Every worker was given the opportunity to freely mention and discuss any symptom that might have presently or recently been bothering him. All complaints were carefully noted and special attention was given to such symptoms as headache, nausea, vomiting, pain or cramps of muscles, joints, or abdomen, weakness, fainting, restlessness, poor appetite, hiccough, diarrhea or constipation, and thirst; any of which might have been overlooked.

Close examination of the data revealed a wide variation and scarcity of symptoms. The most common group of symptoms included cough, upper respiratory complaints, such as hoarseness, sore throat, stopped-up nose, burning sensation of the trachea, throat or nose, and such complaints as scratching, burning, or watering of the eyes.

Seventy-four percent of all the 350 workers were free of cough, upper respiratory, or eye complaints of the above-mentioned types, alone or in combination. Fifty men complained of cough alone, 17 of cough with upper respiratory irritation, 21 of upper respiratory irritation only, 3 of eye irritation only, and 1 of cough and eye irritation in combination.

It is interesting to note that among those working with the smaller amounts of sodium fluoride, 25 percent mentioned these latter special symptoms; where the fluorides were formerly used 24 percent mentioned the symptoms; where the greater amount of fluorides was used 19 percent complained; and in the control group 39 percent mentioned these discomforts. Cough alone was mentioned over twice

as frequently as cough and upper respiratory complaints together, or upper respiratory irritation alone. Eye irritation alone or in combination with cough occurred in less than 1 percent in either case. At the concluson of what might be called the voluntary period of discussion or inquiry, the worker was asked if the fumes, dusts, or smokes or anything about the job bothered him. The usual replies would mention sneezing, coughing, gagging, and choking as the symptoms. Burning of the eyes, nose, or throat was seldom mentioned. Generally, these symptoms were admitted on close inquiry only. They would be described as being of 5 to 15 minutes' duration or until the worker could get out of the smoke or dust. Only very occasionally would these discomforts last over an hour and it was rare to hear of the effect lasting over 24 hours.

No correlation of any significance appeared to result from the analysis by age groups. The old and young appeared to be equally affected or nonaffected by exposures on the job.

PHYSICAL EXAMINATION

General Discussion

In general, the development and nutrition of all four groups was so similar that it made any effect by sodium fluoride seem unlikely. No significant body-weight deviation was noted. The oral temperatures of the workers in all four groups fell within close limits. No significant pallor was noted in any of the workers examined. The skeletal and muscular development was not significantly different in any of the four groups examined. A moderately large number of grooved chests with or without pigeon breasts was noted but the deformity seemed to be due to nutritional defects in infancy. No rigidity, atrophy, or paralysis of muscles was noted. Joint function was not impaired either in the groups exposed to sodium fluoride or in the controls.

Weight Deviation

The percent deviation of each open-hearth worker's weight from the weight of men of similar height and age was calculated from life insurance data. Thus it is possible to determine what proportion were underweight or overweight. As might be expected the percentage (7.1) of the open-hearth workers who were 15 percent or more underweight is less than for most industrial groups studied. A larger proportion underweight were found among cemented tungsten carbide workers, coal miners, smelter workers, and shipyard workers. Only metal miners and truck drivers had a smaller percentage underweight.

On the other hand, 16.8 percent of the open-hearth workers were 15 percent or more overweight. This exceeds the percent overweight for shipyard workers, coal miners, metal miners, and smelter workers.

Plant differences in the percent underweight show that plant D, which had never used sodium fluoride, was the most unfavorable, while plant B, which had not used sodium fluoride recently, was the most favorable. (See appendix, table B.) The percentage of males 15 percent or more overweight was as follows: Plant A, 17.4; plant B, 24.1; plant C, 12.6; and plant D, 17.6. As a whole, open-hearth workers were a strong, muscular group, characteristic of men in an industry which requires heavy physical labor.

Eyes

The eyes were closely observed for possible changes. Conjunctivitis and corneal opacities were rare and not related to sodium fluoride exposures.

Irregularities of the iris were most often present when some definite cause could be found such as neurosyphilis or as the result of an operation.

The lenses were carefully observed under direct and oblique illumination. Slight increases of opacity were recorded but it was usually impossible to decide whether this was the result of cataract formation or merely senile change. The amount of progression in the next few years would demonstrate whether it is actually a cataract in formation. Slight lens opacity was highest in cranemen as a group; 30.4 percent of them being affected as compared to 13.6 percent of the pitmen, who were the next highest group. The highest incidence among cranemen was found in the control plant which tends to minimize fluoride effect as the cause. Analysis of the incidence of slight lens opacity related to degree of exposure to sodium fluoride and duration of work must be carefully considered as the specific job of the individual and his age are related respectively to those factors. There was no increase in lens opacity in workers less than 45 years of age.

Slight opacity was found in 20.8 percent of the workers in the 45 to 54 age group and in 42.4 percent of those 55 years and older. This is certainly evidence that it is an age effect rather than the result of toxicity. The role of infrared radiation should be evaluated in the future since the older men have had a longer exposure to this and the changes may be in part due to this.

Visual Acuity

Visual acuity among open-hearth workers was measured by the Keystone test. If a worker came to the examination wearing glasses he

was tested with his glasses on so that the results should approximate visual ability under normal working conditions.

Table 8 shows the visual acuity of each eye separately for males of specified ages. The percentage of males with 20/20 vision in both eyes was 60.1, under 40 years of age; 26.5, 40 to 49 years; and 6.6, 50 years or over. A better measure of visual ability is the possession of 20/20 vision in at least one eye. The percentage with this visual acuity for the above age groups was 86.9, 49.4, and 10.5. Thus it appears that few open-hearth workers 50 years of age or over had normal vision in either eye.

Table 8.—*Distribution of male open-hearth workers in 4 steel plants by visual acuity (Keystone) of each eye according to age*

Visual acuity left eye	Total	Visual acuity right eye					
		20/20 or better	20/33	20/45	20/60	20/75 or less	Not stated
	Under 40 years						
Total	153	105	46	2	0	0	0
20/20 or better	120	92	27	1	0	0	0
20/33	29	10	18	1	0	0	0
20/45	2	1	1	0	0	0	0
20/60	0	0	0	0	0	0	0
20/75 or less	1	1	0	0	0	0	0
Not stated	1	1	0	0	0	0	0
	40 to 49 years						
Total	83	32	26	15	5	5	0
20/20 or better	31	22	6	2	0	1	0
20/33	29	9	14	4	2	0	0
20/45	13	0	5	7	1	0	0
20/60	7	1	1	2	2	1	0
20/75 or less	3	0	0	0	0	3	0
Not stated	0	0	0	0	0	0	0
	50 years or over						
Total	114	10	27	29	22	18	8
20/20 or better	8	7	1	0	0	0	0
20/33	26	2	13	10	1	0	0
20/45	30	0	12	8	7	3	0
20/60	22	1	0	9	8	4	0
20/75 or less	19	0	0	2	6	11	0
Not stated	9	0	1	0	0	0	8

Comparison with other industrial populations shows that open-hearth workers have a higher percentage of males with visual acuity of 20/20 in at least one eye than do shipyard workers, truck drivers, felt hat workers, or cemented tungsten carbide workers in the age groups under 30 years and 30 to 39 years. In the 40 to 49 and the 50-year or over age groups the position is reversed and open-hearth workers make a poorer showing. For example, age 40 to 49, the

percent with normal vision in at least one eye is 80 for shipyard workers and 87 for cemented tungsten carbide workers, but falls to 49 for open-hearth workers. In the 50-year or over group the contrast is much greater. The first two groups had 65 percent and 81 percent normal whereas open-hearth workers showed less than 10 percent. It should be remembered that these readings are based on actual vision at work, either natural or assisted. Sixty-one percent of the cemented tungsten carbide workers 50 years of age or over wore glasses when tested, but only 35 percent of the open-hearth workers of this age group were so tested. Differences with regard to visual requirements in the two industries might mean that open-hearth workers did not need the same quality of visual acuity, hence a smaller percentage would have secured glasses.

The percentage of males with visual acuity of 20/20 in one or both eyes varied according to age and plant, as follows:

Age	Plant A	Plant B	Plant C	Plant D
Under 30 years	66. 7	100. 0	84. 4	100. 0
30 to 39 years	81. 8	94. 4	86. 8	75. 0
40 to 49 years	69. 2	31. 3	53. 3	38. 5
50 years or over	25. 0	8. 7	2. 9	15. 0

In each plant there was a rapid decrease in the percentage of males with normal visual acuity in at least one eye with advancing age. This change was most marked in plant C and least marked in plant A, both of which use sodium fluoride.

Good eyesight is especially necessary in certain occupations, for example, cranemen who handle ladles containing molten steel. It is of interest to note that 25 percent of the cranemen 40 to 49 years of age had visual acuity in the better eye of only 20/45 or less. At 50 years of age or over 40.6 percent of the cranemen had vision this poor. Seven men operating cranes at the time of this study had visual acuity in the better eye of 20/60 or less. The occupation showing the largest proportion of men with poor vision (20/45 or less in the better eye) was tap, charge, and other workers. Platform workers had the best vision when classified in this manner.

Nose

Nasal mucosa was carefully observed for signs of damage or irritation. Only occasionally was any inflammation found and this was slight. No septal perforation was found in any of the workers.

Throat

The prevalence of pharyngitis among the workers in two plants was determined according to their exposure to sodium fluoride. A scale consisting of four degrees of exposure, based on the concentration of fume and length of time in this concentration, was established on the basis of the engineering findings. The lowest percentage (52.0) of normal throats was found in the greatest degree of exposure. Mild pharyngitis was found to increase with increasing exposure ranging from 8.3 percent in the first degree to 20.0 percent in the fourth degree. Cough alone tended to decrease with increasing exposure. From this it seems evident that cough is not related to sodium fluoride concentrations. Pharyngitis, with or without cough, tended to increase with increasing exposure; the percentages in the first degree and in the fourth degree being 10.4 and 36.0 for pharyngitis without cough and 22.9 and 48.0 for pharyngitis with cough.

Workers in the other two plants were said to have no or minimal exposure to sodium fluoride. This material had never been used in one plant but had been used at some time in the past in the other plant. Among workers with no and minimal exposures 67.5 percent had normal throats and 14.1 percent had mild pharyngitis. Pharyngitis with cough was found in 7.4 percent of these workers, cough alone in 17.2 percent and pharyngitis without cough in 20.9 percent.

When individual plants were considered it was found the plant where sodium fluoride had never been used had the highest percentage of workers with pharyngitis. No age trend was apparent in connection with these findings.

In conclusion it appears that no severe pharyngeal damage results from exposure to sodium fluoride. A slight degree of pharyngitis may possibly be caused by sodium fluoride, tar smoke, or sulfur dioxide fumes but it is difficult to separate the effects of these three.

Cardiovascular

Heart disorders were classified under the same broad etiological headings followed in certain other Public Health Service investigations of industrial workers. This classification is based on the outline prepared by the heart committee of the New York Tuberculosis and Health Association,[10] sponsored by the American Heart Association and discussed by Hedley.[11] Many of the workers observed and diagnosed as having arteriosclerotic or hypertensive heart disease were comparatively symptom free, especially among younger individuals and could, *possibly*, be classified as preclinical or potential heart dis-

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[10] Criteria for the Classification and Diagnosis of Heart Disease. 3d ed. New York Tuberculosis and Health Assoc., New York, 1932.

[11] Hedley, O. F.: Studies of Heart Disease Mortality. Pub. Health Bull. No. 231.

ease. A systolic blood pressure of more than 150 millimeters Hg and a diastolic pressure of more than 100 was interpreted as showing essential hypertension.

As shown in table 9 arteriosclerotic-hypertensive heart disease was more frequently observed among open-hearth workers than among other groups of workers recently studied by the Public Health Service. The excess for open-hearth workers is most marked for the age groups 25 to 34 and 35 to 44 years. With respect to the incidence of rheumatic heart disease, open-hearth workers do not differ greatly from the others.

Table 9.—*Percentage of male open-hearth workers in the steel industry with arteriosclerotic-hypertensive heart disease or rheumatic heart disease classified according to age and compared with other male industrial workers*

Industrial group	Age in years					
	Total	15 to 24	25 to 34	35 to 44	45 to 54	55 or over
	Percent with arteriosclerotic-hypertensive heart disease					
Open-hearth workers	17.4	0.0	5.6	9.9	24.8	39.0
Cemented tungsten carbide workers [1]	3.9	.5	1.5	2.8	7.3	22.1
Shipyard workers [2]	9.4	.7	3.1	9.6	17.3	57.6
Utah coal mine workers [3]	5.7	1.3	2.9	2.1	11.4	35.7
Utah metal mine workers [4]	6.7	4.8	1.2	7.6	13.5	31.1
Utah smelter workers [5]	8.6	3.1	1.7	4.4	14.3	37.2
Pottery workers [6]	4.5	0	.9	2.2	11.3	25.5
Storage battery workers [7]	12.3	0	1.6	7.4	29.9	41.3
Truck drivers [8]	6.1	5.2	4.7	7.1	18.4	25.0
	Percent with rheumatic heart disease					
Open-hearth workers	2.6	0.0	3.4	0.0	4.0	3.4
Cemented tungsten carbide workers	.9	1.6	.9	.5	.6	.9
Shipyard workers	1.6	3.1	1.6	1.3	.3	1.2
Utah coal mine workers	2.8	2.5	.6	4.2	4.5	3.6
Utah metal mine workers	2.3	2.4	1.9	2.3	3.8	2.2
Utah smelter workers	.6	0	1.1	.3	.7	.7
Pottery workers	1.0	1.1	.7	1.1	1.8	0
Storage battery workers	1.2	0	2.0	1.4	.6	0
Truck drivers	1.7	0	1.9	2.6	0	0
	Total number of workers examined					
Open-hearth workers	350	20	89	81	101	59
Cemented tungsten carbide workers	1,533	191	658	394	177	113
Shipyard workers	2,835	421	1,138	799	307	170
Utah coal mine workers	507	79	170	142	88	28
Utah metal mine workers	727	83	323	172	104	45
Utah smelter workers	1,391	130	458	387	279	137
Pottery workers	1,627	350	549	370	221	137
Storage battery workers	757	74	246	217	157	63
Truck drivers	886	135	485	224	38	4

1 Unpublished data.
2 Pub. Health Bull. No. 298.
3 Pub. Health Bull. No. 270.
4 Pub. Health Bull. No. 277.
5 Working Environment and Health of Workers in Bituminous Coal Mines, Nonferrous Metal Mines, and Nonferrous Smelters in Utah, by Division of Industrial Hygiene, USPHS, and Utah State Board of Health, Nov. 1940.
6 Pub. Health Bull. No. 244.
7 Pub. Health Bull. No. 262.
8 Pub. Health Bull. No. 265.

Arteriosclerotic-hypertensive heart disease was found present in 17.4 percent of the 350 open-hearth workers. The percentage in individual plants ranged from 8.3 to 22.2, with the lower incidence in the two sodium fluoride-using plants. Essential hypertention accounted for 11.7 percent of the workers examined. When individual plants are considered it is found that 6.2 and 10.1 percent of the workers in the two sodium fluoride-using plants, 11.0 percent of the control plant and 20.6 percent of those working in the plant where sodium fluoride had been used in the past, had essential hypertension.

Less than 1 percent of the total employees were considered to be suffering from decompensated hypertensive heart disease while 4.9 percent were said to have the compensated type. The control plant showed the highest percentage with the compensated type of this disease (9.0 percent) while one of the fluoride-using plants had none although it had the highest percentage of the decompensated type (2.1 percent).

Only one case of syphilitic heart disease was suspected. There were functional heart murmurs in 3.1 percent of the workers examined. The highest incidence of this was in the two sodium fluoride-using plants while the control plant had none.

Rheumatic valvular disease was suspected in 2.6 percent of the total workers examined. In the two plants using sodium fluoride the incidence was less than in the two nonfluoride-using plants: 2.1 percent and 2.2 percent in the former and 3.0 percent and 3.2 percent in the latter.

No cardiovascular change was apparent as a result of sodium fluoride exposure in the manufacture of steel.

Blood Pressure

The mean systolic blood pressure of males working at the open hearth was 132.7 which is higher than that of certain other industrial groups studied by the Public Health Service. (See table 10.) These latter were 10,000 Industrial Workers [12] with a mean of 129, truck drivers with 128, shipyard workers with 126, Utah soft coal and metal mine workers each with 125, and cemented tungsten carbide workers with 122. Mean diastolic blood pressure for open hearth workers was 84, which was also the highest of the groups mentioned above. Truck drivers averaged 83, Utah soft coal mine workers 81, Utah metal mine workers 80, shipyard workers 78, 10,000 Industrial Workers 77 and

[12] Public Health Bulletin No. 162.

cemented tungsten carbide workers 74; as will be seen when table 10 is studied.

Table 10.—*Comparison of mean systolic and diastolic blood pressures of males in open-hearth department of 4 steel plants and of other industrial groups*

Age (years)	Open-hearth workers	Cemented tungsten carbide workers [1]	Shipyard workers [2]	Utah metal mine workers [3]	Utah soft coal mine workers [4]	Truck drivers [5]	10,000 industrial workers [6]
	Mean systolic blood pressure						
Total	133	122	126	125	125	128	129
Under 25	122	113	117	124	122	126	123
25 to 29	124	118	123	123	124	129	126
30 to 34	126	121	123	122	124	129	127
35 to 39	127	120	126	122	122	127	128
40 to 44	131	122	127	127	126	128	130
45 to 49	132	127	131	127	123	132	135
50 or over	144	137	140	135	134	142	142
	Mean diastolic blood pressure						
Total	84	74	78	80	81	83	77
Under 25	77	67	72	78	78	80	72
25 to 29	81	72	77	78	79	82	75
30 to 34	82	73	77	77	81	84	77
35 to 39	82	75	80	78	80	82	79
40 to 44	85	78	80	84	84	83	80
45 to 49	85	78	82	83	81	88	81
50 or over	87	81	85	87	86	88	83

[1] Unpublished data.
[2] Pub. Health Bull. No. 298.
[3] Pub. Health Bull. No. 277.
[4] Pub. Health Bull. No. 270.
[5] Pub. Health Bull. No. 265.
[6] Pub. Health Bull. No. 162.

The mean systolic blood pressures for males in the fluoride-using plants were 128.4 and 131.9 and for the nonfluoride-using plants they were 133.0 and 135.7. As shown in appendix, table C, plant D had the highest mean systolic and diastolic blood pressures in the age groups under 25 years, 25 to 29 years, 30 to 34 years, 45 to 49 years, and 65 years or over.

Arterial hypertension (systolic blood pressure in excess of 150 millimeters Hg) was found in only 1.9 percent of the open-hearth workers 20 to 29 years of age as compared with 4.2 percent of the 10,000 Industrial Workers of the same age who had the highest percentage. In all of the industrial groups this condition increased with age although the percentage of open-hearth workers 60 to 69 years of age was slightly less than those 50 to 59 years. Table 11 shows the fluctuation with age for the several groups of industrial workers.

Table 11.—*Percentage of male open-hearth workers in 4 steel plants with arterial hypertension*[1] *according to age, compared with other male industrial workers*

Industrial group	Age in years				
	20 to 29	30 to 39	40 to 49	50 to 59	60 to 69
	Percent with arterial hypertension				
Open-hearth workers	1.9	6.1	15.7	35.2	33.3
Cemented tungsten carbide workers [2]	1.4	2.3	7.1	16.1	34.0
Shipyard workers [3]	2.3	3.9	7.7	16.7	34.1
Utah workers [4]	2.2	1.9	5.6	21.6	31.8
Pottery workers [5]	3.2	5.8	13.7	21.2	43.1
10,000 male industrial workers [6]	4.2	7.3	16.4	28.5	47.9
Storagebattery workers [7]	3.3	6.8	18.7	29.5	45.2
	Total number of workers examined				
Open-hearth workers	53	99	83	91	21
Cemented tungsten carbide workers	505	573	252	137	50
Shipyard workers	688	1,192	507	216	82
Utah workers	764	838	570	329	88
Pottery workers	569	447	256	160	51
10,000 male industrial workers	3,248	3,293	1,947	818	234
Storagebattery workers	182	221	219	95	31

[1] Refers to systolic blood pressure in excess of 150 millimeters Hg.
[2] Unpublished data.
[3] Pub. Health Bull. No. 298.
[4] Working Environment and Health of Workers in Bituminous Coal Mines, Nonferrous Metal Mines, and Nonferrous Smelters in Utah, by Division of Industrial Hygiene, USPHS, and Utah State Board of Health, Nov. 1940.
[5] Pub. Health Bull. No. 244.
[6] Pub. Health Bull. No. 162.
[7] Pub. Health Bull. No. 262.

Skin

Many of the common skin disorders such as acne vulgaris were noted, but only a few cases suggesting the possibility of fluoride dermatitis were seen. One of these cases showed purple-red patches on the wrists considered to be post inflammatory, possibly as a result of sodium fluoride dermatitis. No vesiculation, ulceration, pruritis, or necrosis was seen as might have been expected from sodium fluoride damage. It appears that sodium fluoride plays only a very minor role, if any, in causing dermatitis among these workers. Irregularities, mottling, pitting or curving of the nails described by Spira[13] and others as an early sign of fluorosis were not noted.

X-RAY INTERPRETATIONS

General Discussion

The classification used in other investigations of the Public Health Service was selected to describe the appearance of the chest X-ray films. The lung-field markings were divided into linear, granular, and nodular as follows:

[13] Spira, Leo; Mottled nails. An early sign of fluorosis. *Jour. Hyg.*, 43: 69, Jan. 1943.

Linear.—Normal lung markings and first degree exaggeration of linear pulmonic markings. Second degree exaggeration of linear pulmonic markings, with or without beading.

Granular.—First degree diffuse ground glass or grainy appearance, not obliterating linear markings. Second degree diffuse ground glass or grainy appearance, obliterating linear markings.

Nodular.—First degree disseminated nodules up to size of miliary tubercles. Second degree disseminated nodules exceeding 1 millimeter in size, emphysema present, usually.

Table 12 shows the percentage of white males in the open-hearth department whose chest X-ray revealed exaggerated lung-field markings of first degree ground glass or greater compared with other industrial groups. Age specific comparisons indicate that open-hearth workers had the most unfavorable experience among workers 25 to 34 years of age, but among workers 35 to 44, 45 to 54, and 55 years of age or over they made a more favorable showing than Utah metal mine and coal mine workers. For each age group over 24 years shipyard workers and cemented tungsten carbide workers showed lower percentages with ground glass or greater markings than did open-hearth workers.

Table 12.—*Percentage of white males in the open-hearth department of 4 steel plants whose chest X-rays showed exaggerated lung-field markings of first degree ground glass or greater, compared with other industrial groups, by age*

Age (years)	Open-hearth workers	Cemented tungsten carbide workers [1]	Shipyard workers [2]	Utah soft coal mine workers [3]	Utah metal mine workers [4]	Utah smelter workers [5]
Total	12.0	2.4	3.2	9.0	14.2	6.4
15 to 24	0	.5	.5	0	0	0
25 to 34	5.4	1.0	3.0	1.8	3.8	1.1
35 to 44	10.4	2.0	3.0	11.7	21.7	7.3
45 to 54	18.5	6.8	6.1	21.2	36.3	13.7
55 or over	16.3	8.0	6.1	25.9	35.5	13.2

[1] Unpublished data.
[2] Pub. Health Bull. No. 298.
[3] Pub. Health Bull. No. 270.
[4] Pub. Health Bull. No. 277.
[5] Working Environment and Health of Workers in Bituminous Coal Mines, Nonferrous Metal Mines, and Nonferrous Smelters in Utah, by Division of Industrial Hygiene, USPHS, and Utah State Board of Health, Nov. 1940.

As may be observed from appendix, table D, there is no indication that the use of fluoride had any influence on the lung-field findings. As the granular markings are divided into first- and second-degree stages, the latter and those of the nodular group will be described more specifically in the next section.

Symptoms and Physical Findings Associated With Marked Granular and Nodular Lung-Field Markings

Six X-ray films were rated as showing second degree granular lung-field markings. In no instance was the film considered in this ad-

vanced stage of fibrosis if linear lung-field markings were visible. Previous studies by the Public Health Service of industrial environments and workmen have demonstrated that a diagnosis of silicosis was made on a basis of second degree ground glass lung-field markings as shown by a satisfactory X-ray film of the chest, if supported by symptoms and/or physical findings excluding other diseases accompanying such chest X-ray markings, and accompanied by an occupational history revealing a prolonged exposure to dust containing silica.

Two of the six cases did not have one or two of the three factors in sufficient length of work exposure accompanied by supporting symptomatology or physical disability to warrant a diagnosis of silicosis suspected with such lung-field markings. Four of the workmen with second degree granular lung-field markings were considered as having early first degree silicosis. Their case histories are outlined below:

1. 25 years at open hearths.
   2 years in iron foundry.
   3 colds in past 12 months.
   Frequent pains in hips, legs and arms.
   Cough.
   Hoarseness.
   Thin.
   Blood pressure 92/54.
   GG 2 with obliterated angles.
2. 37 years at open hearths.
   Stomach swells with gas.
   Thin.
   Blood pressure 126/86.
   Tonsils infected.
   Pharynx slightly inflamed.
   GG 2 with hilar calcification on the right and mild emphysema.
3. 5 years at open hearths.
   8 years in brick and tile plants (kiln placer).
   7 years in coal mines (loader).
   1 year in pottery (mold burner).
   Bronchitis for 25 years.
   Sinus infection in 1942.
   Cough.
   Thin.
   Blood pressure 172/90.
   Hypertensive heat disease—compensated.
   GG 2 with thickened interlobular markings.
4. 27 years at open hearths.
   Uses cough drops.
   Pneumonia in 1946 and 1947.
   Asthma for years.
   Dyspnea for years.
   Cough.
   Thin.
   Barrel chest and overexpanded.
   Percussion—hyperresonant.

Auscultation—wheezing throughout.
Blood pressure 160/66.
GG 2 with hilar and parenchymal calcification on the left.

Two workers presented X-ray films which assumed a first-degree nodular appearance. On the basis of the occupational exposure, symptoms, physical findings, and roentgenological interpretations they were diagnosed as silicosis I. Their case histories are as follows:

1. 31 years at open hearths.
   7 years in foundries (molder helper).
   Lumbago in 1938.
   Medium build and nutrition.
   Pigeon and grooved chest.
   Blood pressure 130/86.
   Nodular 1 with hilar calcification on right.
2. 31 years at open hearths.
   4 years in hard coal mines (picking slate).
   Uses cough medicine.
   Sinus infection for 2 years.
   Dyspnea for few years.
   Occasional cough in daytime.
   Medium build and nutrition.
   Blood pressure 138/88.

Pulmonary Tuberculosis

A number of chest X-ray films with varying degree of abnormal markings were reviewed by a member of the staff of the Tuberculosis Control Division of the Public Health Service. It was believed that five of the films warranted a classification of tuberculosis. After a subsequent review of the films, histories, and physical findings, two were considered to be probably active; one moderately advanced and the other far advanced. The other three were classified as minimal with uncertain activity. It was recommended that the latter three cases be restudied by the workers' private medical consultants after a 3 months' interval. It was interesting to note that four of the five were workers from the control plant. The two "active" cases furnished either a suggestive history or physical findings, or both. Their laboratory findings were essentially negative.

Of the less suspiciously active cases one had negative past and present medical history and physical examination. The red blood count was 4,600,000 (differential: neutrophils segmented 38, neutrophils bands 2, lymphocytes 53, monocytes 5, eosinophils 1, basophils 1, reticulocytes 0), white blood count 12,000 and hemoglobin 14 grams. Urine and Kahn negative.

The second case gave a history of influenza in 1919 and complained of malaise, nervousness, headache, and one recent spell of nausea and vomiting. The physical examination data were essentially negative. The red blood count was 4,800,000 (differential: neutrophils segmented

63, neutrophils bands 4, lymphocytes 31, monocytes 2, eosinophils 0, basophils 0, reticulocytes 0), white blood count 8,400 and hemoglobin 15 grams. Urine and Kahn negative.

The third case gave a history of influenza in 1918 and pleurisy in 1946, with symptoms of dizziness and irritability. The physical examination was essentially negative. The red blood count was 4,-900,000 (differential: neutrophils segmented 52, neutrophils bands 2, lymphocytes 40, monocytes 3, eosinophils 2, basophils 1, reticulocytes 0), white blood count 11,500 and hemoglobin 15 grams. Urine negative and Kahn unknown.

Long-Bone X-ray Films

The X-ray films of the long bones of the left forearm were examined for structural changes, such as increased density, narrowing of the marrow cavity, increased thickening or roughening along the areas where ligamentous attachments would be expected and any changes in the bony structure itself. It was concluded that such abnormal changes were not present.

LABORATORY

Blood Test for Syphilis

There were nine blood specimens which were reported to have positive serologic tests for syphilis and two reported as doubtful. The rate among white males was 1.6 percent and among colored males 23.8 percent, or 2.7 percent of all males. There were no positive tests at plant C while the other three plants each had 2.2 percent with positive reports.

Hemoglobin Determination

The largest percentage of workmen with 16 grams or over of hemoglobin per 100 cubic centimeters of blood was found among those who were working in the plant using the greater amount of sodium fluoride and lowest in the control plant. A greater relative number of workers in the younger age group (under 45 years) and among those who had spent less than 10 years in open-hearth work, had hemoglobin levels of 16 grams or above. In general, hemoglobin levels fell within normal limits and no sodium fluoride effect was demonstrated. (See appendix, table E.)

Red and White Blood Cell Counts

White blood cell counts of 11,000 or more were found less commonly in the plant using the greater amount of sodium fluoride and

most often in the plant which had used sodium fluoride in the past. The differential blood count was normal in all cases except three which had eosinophilia. (Persons with 10 or more percent eosinophils were considered excessive.) The highest eosinophil count was 26 percent but the history and physical findings indicate that asthma was the cause of this. No abnormal or immature white blood cells were noted. The morphology of the red blood cells was within normal limits and no stippling or other toxic effect was noted. (See appendix, tables F and G.)

Urinalysis

Albuminuria was found in only four workers: One in the plant using the smaller amount of sodium fluoride and three in the plant which used the larger amount of sodium fluoride. This is a small percentage and may be coincidental in its occurrence in the plants using sodium fluoride.

Glycosuria was found in two workmen employed in the control plant. It was found in one worker who also had albuminuria, in the plant using the larger amount of sodium fluoride.

Fluorides in Urine

The data indicate that the urinary levels resulting from the examination of 38 specimens are within normal limits, thus correlating quite well with the findings revealed by physical examination.

SUMMARY OF MEDICAL FINDINGS

1. In the course of the investigation the following symptoms were considered to be most significant and commonly found. The most common were cough and upper respiratory complaints, such as hoarseness, sore throat, and congestion of the nose. Burning, watering, and scratching sensations of the eyes were occasionally encountered. Very temporary symptoms, such as sneezing, cough, gagging, and choking occurred in the presence of fume, smoke, and dust. Workmen of the control plant complained of cough more often than those exposed to fluoride. Nausea and vomiting were occasionally reported. Symptoms frequently persisted for a period of from 5 to 10 minutes. Occasionally they persisted for an hour or so, and very infrequently for as long as 24 hours. Inquiry was made concerning the classical symptoms commonly associated with fluorosis. These were not found in significant numbers.

2. The nutrition, development, color, posture, and gait were within normal limits. Joint function was good and no rigidity or atrophy of the muscles was noted.

3. Conjunctivitis and corneal opacities were infrequent and were not associated with sodium fluoride exposure. The increased opacity of the lens was directly related to age.

4. The nasal mucosa occasionally showed slight inflammation but no septal perforations were present.

5. Pharyngitis alone was found most often in the control plant.

6. No pulmonary findings were related to sodium fluoride exposure.

7. Eleven and seven-tenths percent of all the workers examined had essential hypertension. Incidence of suspected hypertensive heart disease was 9 percent in the control group, which was about twice as much as the highest other group. No cardiovascular change was apparent as the result of exposure to sodium fluoride.

8. Only a few cases suggesting the possibility of fluoride dermatitis were seen. Irregularities and mottling of the nails as described by Spira were not found.

9. The lung-field markings compare favorably with those of other industrial groups previously studied. No change was seen to occur as a result of exposure to sodium fluoride. There were two cases of silicosis in the first degree and four considered to be approaching early silicosis. Two cases were presumed to be in a moderate to advanced stage of active pulmonary tuberculosis, and three in a minimal stage of inactive pulmonary tuberculosis.

10. The arm-bone X-rays were carefully examined and no signs of fluorosis could be found.

11. Laboratory examinations of the blood and urine revealed no toxic effect. Urinary fluoride levels were below levels which had been shown safe in experimental work.

CONCLUSIONS FROM MEDICAL FINDINGS

1. Fume, smoke, and dust encountered at the open hearths induce an upper respiratory symptom complex which may be irritating and annoying.

2. According to the data on symptoms by plants, there is an inverse relationship of the symptomatology to the exposure to sodium fluoride.

3. No severe pharyngeal damage results from exposure to sodium fluoride. A slight degree of pharyngitis may possibly be caused by sodium fluoride, tar smoke, or sulfur dioxide fumes. It is difficult to separate the effects of these three environmental factors.

4. On a basis of physical and X-ray findings, there were no definite changes attributable to sodium fluoride.

Oral Findings

INTRODUCTION

Sodium fluoride has become increasingly important to the oral health of mankind since the discovery of this substance as an agent capable of reducing caries activity in the teeth of children. Exposure to sodium fluoride during adult life has not been demonstrated as beneficial in caries prevention.

Certain of the fluoride substances such as hydrofluoric acid (HF) and hydrofluosilicic acid (H_2SiF_6) produce characteristic lesions of the soft oral tissues. The lips, gingivae, oral mucosae, and tongue may show inflammatory reaction to exposure of these acids. Sodium fluoride (NaF) does not produce any characteristic open lesions in the mouth as shown by experimental data. Cryolite (Na_3AlF_6), another sodium salt of fluorine, does not produce any oral manifestations of soft tissue change. However, Roholm [1] and other investigators have shown that total fluoride content of tooth substance in the jaws is increased in adults exposed to sodium fluoride (NaF) and cryolite (Na_3AlF_6). Bone tissue of the jaws, which is capable of constant interchange of calcium salts, increases in fluoride content by the deposition of the fluoride in some form within the bony structure. Explanation for the increased fluoride concentrations in tooth structure is based on the formation of secondary dentin within the pulpal cavity and by development of hypercementosis of the tooth roots during prolonged periods of exposure to sodium fluoride (NaF).

In this survey the employees were exposed to varied concentrations of sodium fluoride during their daily work. The problem was to ascertain whether or not the levels of exposure to sodium fluoride (NaF) were sufficient to cause any deleterious effect in the oral tissues and structures.

CLINICAL ORAL EXAMINATION

Clinical oral examination consisted of a detailed inspection of all oral tissues and structures by the examining dental officers. The lips,

[1] Roholm, Kaj: Flourine Intoxication. H. K. Lewis & Co., London, 1937.

tongue, palate, uvula, oral mucosae, teeth, and supporting structure, salivary glands and ducts, and the mandible were inspected and all observations were recorded.

Radiodontic films were used as a diagnostic aid in completion of the oral inspection. Two intra-oral bite-wing exposures (Eastman DF43) and a lateral 5- by 7-inch extra-oral view of the left mandible were made in the majority of employees.

All oral findings, whether normal or abnormal, were recorded on an examination form developed for use in this survey. The individuals who were found to have abnormal oral conditions were informed of their abnormalities and advised to have them corrected as soon as possible.

GENERAL FINDINGS

Accrued defects of the oral tissues and structures considered to be nonoccupational in origin were classified in this category. The frequency with which these abnormal conditions appeared among the 350 male employees surveyed compared with 1,514 male cemented tungsten carbide workers is shown in table 13. The range of accrued oral defects in this population is similar to that observed in other industrial and nonindustrial populations.

SPECIFIC FINDINGS

The findings in this category indicate that factors present in the environment cause certain tissue reactions. Tissue response to intermittent or constant irritants is characterized by hyperemia, observed as an increase in color intensity, and keratosis or a characteristic thickening of the mucous membranes. The degree of hyperemia and keratosis is dependent on the severity of tissue reaction and constancy of the irritant factor or factors. Comparison of clinical observations among the groups examined shows a course of tissue change which occurred in varied periods of exposure.

Clinical findings were recorded with the knowledge that many factors which may have influenced those findings were present in the environment, either at a specific occupation or in a combination of several occupations.

Table 14 shows that inflammation was more frequent among the males working in plants which used sodium fluoride than in the plants which did not use this substance. This was observed for each of the oral tissue groups. No consistent differences were noted for keratosis or neoplasm.

Table 13.—*Comparison of the incidence of abnormalities in specified oral tissues and structures among male workers in the open-hearth department of the steel industry and in the cemented tungsten carbide industry*

Oral tissues or structures	Open-hearth workers		Cemented tungsten carbide workers[3]	
	Number	Percent	Number	Percent
Lips	93	26.6	205	13.5
Tongue	96	27.4	149	9.8
Gingivae	267	76.3	1,153	76.2
Oral mucous membrane	185	52.9	746	49.3
Palate	149	42.6	461	30.5
Teeth:				
Caries[1]	155	52.7	869	68.2
Calculus[2]	195	78.3	781	61.3
Attrition[1]	40	13.6	124	9.7

[1] Based on number of persons with teeth.
[2] Based on number of persons with teeth minus those with no information on this item.
[3] Unpublished data.

INTERPRETATION OF FINDINGS

Substances found to exist in the occupational environment were sodium fluoride, anthracene, sulfur dioxide, ferric oxide, quartz, dolomite, and slag dust. Therefore, the hard and soft tissues of the oral cavity were exposed to chemical as well as mechanical factors.

Individuals exposed to high intensity of radiant heat arising from the face of open ladles and ingots filled with molten metal show an increase in the abnormality of the lip mucosae. The drying (desiccating) effect of this exposure contributed to formation of superficial fissures, with or without hemorrhage, and keratoses. Low-grade secondary infections were observed on the lips of some employees. Abnormalities of the lips appear to increase after 55 years of age. Table 15 shows that the percentage with abnormalities of the velum (soft tissue of the posterior of the mouth) and uvula (the small tissue appendage in the posterior mouth) was high in all groups examined, being greater in the sodium fluoride-using plants (A and C) than in the nonsodium fluoride-using plants (B and D). The percentages for these two groups are 95.2 and 57.7, respectively. Age does not appear to affect the incidence of this condition. It cannot be stated with certainty that the great difference in prevalence of this condition was due to the presence of, or exposure to, sodium fluoride.

Attempted correlation of this specific finding with other physical findings did not provide sufficient information to form any definite conclusions.

Review of the roentgenographs fails to show any conditions of pathosis occurring in the bone which may be associated with exposure to sodium fluoride dust and fume.

Table 14.—*Percentage of male workers in the open-hearth department of 4 steel plants with inflammation, keratosis and neoplasm in specified oral tissues or structures, grouped according to plants using sodium fluoride and plants not using sodium fluoride*

Oral tissues or structures	Pathological conditions					
	Inflammation		Keratosis		Neoplasm	
	NaF plants	Non-NaF plants	NaF plants	Non-NaF plants	NaF plants	Non-NaF plants
	Number					
Lips	2	1	16	24	0	2
Tongue	19	5	1	1	1	2
Gingivae	142	96	5	14	0	0
Oral mucous membrane	58	20	63	51	0	1
Palate	44	11	28	32	4	0
Uvula and velum	177	90	0	0	6	3
	Percent					
Lips	1.1	0.6	8.6	14.7	0.0	1.2
Tongue	10.2	3.1	.5	.6	.5	1.2
Gingivae	75.9	58.9	2.7	8.6	0	0
Oral mucous membrane	31.0	12.3	33.7	31.3	0	.6
Palate	23.5	6.7	15.0	19.6	2.1	0
Uvula and velum	94.7	55.2	0	0	3.2	1.8

Table 15.—*Percentage of male workers in the open-hearth department of 4 steel plants with abnormalities in specified tissues or structures, grouped according to plants using sodium fluoride and plants not using sodium fluoride*

Plants	Total persons examined	Persons edentulous	Oral tissues or structures						
			Lips	Tongue	Gingivae	Oral mucous membrane	Palate	Uvula and velum	Teeth (caries) [1]
	Number								
Total	350	56	93	96	267	185	149	272	155
NaF	187	25	49	39	154	113	94	178	81
Non NaF	163	31	44	57	113	72	55	94	74
	Percent								
Total	100.0	16.0	26.6	27.4	76.3	52.9	42.6	77.7	52.7
NaF	100.0	13.4	26.2	20.9	82.3	60.4	50.3	95.2	50.0
Non NaF	100.0	19.0	27.0	35.0	69.3	44.2	33.7	57.7	56.1

[1] Percentages based on number of persons with teeth.

Heavy concentrations of dust in this occupational environment as shown by the environmental study, may account for the high prevalence of premature attrition in the teeth of men in the younger age groups.

SUMMARY OF ORAL FINDINGS

1. Three hundred and fifty workers of the open-hearth divisions in four steel plants were given clinical oral examinations.

2. The outstanding soft-tissue abnormality in this group of men was inflammation of the uvula and velum (soft palate).

3. The outstanding hard tissue abnormality was premature attrition of occluding tooth surfaces. Attrition did not vary much in incidence among the four groups examined.

4. Roentgenograms of the posterior teeth (bite-wings) and left lateral jaw (5- by 7-inch exposure) were obtained.

CONCLUSIONS FROM ORAL FINDINGS

1. Exposure to abrasive dust caused premature attrition of the occluding tooth surfaces allowing for decrease in vertical dimension of jaw relationship.

2. Repeated exposure to irritant factors in the occupational environment may produce tissue thickening on vulnerable areas of the oral mucosae.

3. Exposure to sodium fluoride had little or no disabling effect on the tissues and structures of the oral cavity. Sodium fluoride did not produce demonstrable tissue necrosis when introduced into the oral cavity in atmospheric concentrations as found in the occupational environments investigated. However, sodium fluoride in combination with other fumes and dusts may be a contributing factor in producing soft-tissue inflammation in the oral cavity.

4. The high incidence of oral abnormalities found in this group of male open-hearth workers places the oral health status of this population at a low level.

5. Inflammatory condition of the exposed mucosae indicates that tissue irritation by mechanical action, as well as chemical action, was possibly due to environmental contaminants.

RECOMMENDATIONS FROM ORAL FINDINGS

1. An industrial oral health service program might be developed in each of the four plants in which employees were examined. These programs would contribute much to raise the oral health level in a majority of the employees.

2. Protection of employees' oral tissues and structures may be accomplished by the use of a lightweight face mask which would filter the environmental air, thereby reducing the amount of abrasive dusts and particles of chemical substances which may be inhaled by way of the oral cavity.

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Appendix Tables

Table A.—*Previous occupation of male open-hearth workers in 4 steel plants according to plant*

Previous occupation	Number					Percent				
	Total	Plant A	Plant B	Plant C	Plant D	Total	Plant A	Plant B	Plant C	Plant D
Total	350	48	63	139	100	100.0	100.0	100.0	100.0	100.0
None	35	5	3	18	9	10.0	10.4	4.8	12.9	9.0
Agriculture, forestry, and fisheries only	37	4	7	13	13	10.6	8.3	11.1	9.4	13.0
Agriculture, forestry, fisheries, and trade or service	20	1	3	6	10	5.7	2.1	4.8	4.3	10.0
Trade or service only	88	10	12	52	14	25.2	20.8	19.0	37.4	14.0
Mining or quarrying	33	7	6	9	11	9.4	14.6	9.5	6.5	11.0
Foundry	18	2	6	5	5	5.1	4.2	9.5	3.6	5.0
Other dusty trades	18	6	2	4	6	5.1	12.5	3.2	2.9	6.0
Manufacturing industry	8	1	4	0	3	2.3	2.1	6.4	0	3.0
All other	93	12	20	32	29	26.6	25.0	31.7	23.0	29.0

Table B.—*Distribution of male open-hearth workers in 4 steel plants by percent weight deviation from the average weight of men of their height and age according to life insurance tables, by plant*

Percent weight deviation from average	Number					Percent				
	Total	Plant A	Plant B	Plant C	Plant D	Total	Plant A	Plant B	Plant C	Plant D
Total	322	46	58	127	91	100.0	100.0	100.0	100.0	100.0
25 to 34 below	3	0	0	1	2	0.9	0	0	0.8	2.2
15 to 24 below	20	3	2	7	8	6.2	6.5	3.4	5.5	8.8
5 to 14 below	77	8	16	31	22	23.9	17.4	27.6	24.4	24.2
±5	100	20	11	43	26	31.1	43.5	19.0	33.9	28.5
5 to 14 above	68	7	15	29	17	21.1	15.2	25.9	22.8	18.7
15 to 24 above	38	7	9	8	14	11.8	15.2	15.5	6.3	15.4
25 to 34 above	11	1	4	6	0	3.4	2.2	6.9	4.7	0
35 or more above	5	0	1	2	2	1.6	0	1.7	1.6	2.2
Mean (percent)	+2.2	+2.2	+5.0	+1.8	+1.0					
Standard deviation (percent)	13.3	11.5	13.9	12.9	13.9					

Table C.—*Mean systolic and diastolic blood pressures of male open-hearth workers in 4 steel plants according to age and plant*

Age (years)	Total	Plant A	Plant B	Plant C	Plant D
	Systolic blood pressure				
Total	132.7	128.4	133.0	131.9	135.7
Under 25	121.7	0	*90.0*	121.8	125.5
25 to 29	124.1	*118.0*	123.2	124.0	128.8
30 to 34	126.0	128.5	123.8	125.3	128.8
35 to 39	126.9	125.2	116.6	132.2	119.7
40 to 44	130.7	134.6	148.8	126.0	120.5
45 to 49	132.1	126.2	130.7	126.0	141.2
50 to 54	138.8	*128.7*	138.4	138.9	140.6
55 to 59	148.8	*118.7*	*161.5*	152.0	148.5
60 to 64	143.5	*124.0*	*152.0*	*156.0*	132.4
65 or over	152.2	*150.0*	*138.0*	*145.0*	*163.5*
	Diastolic blood pressure				
Total	84.0	83.2	83.4	83.9	85.0
Under 25	77.3	0	*50.0*	77.5	80.5
25 to 29	80.5	*78.0*	76.4	81.3	82.8
30 to 34	81.7	80.3	78.9	82.6	83.2
35 to 39	81.7	82.0	78.6	82.8	80.6
40 to 44	85.4	87.1	92.0	84.6	80.7
45 to 49	85.4	85.7	83.6	82.8	88.0
50 to 54	85.9	*80.0*	85.9	88.6	84.4
55 to 59	90.4	*74.7*	*96.0*	91.1	91.3
60 to 64	88.2	*84.0*	*91.3*	*92.0*	84.0
65 or over	82.1	*70.0*	*78.0*	*78.7*	*89.5*

Note.—Figures in italics are based on less than 5 persons

Table D.—*Type of lung-field markings observed in chest roentgenograms of male open-hearth workers in the steel industry according to plant and age*

Type of lung-field marking	Number					Percent				
	Total	Plant A	Plant B	Plant C	Plant D	Total	Plant A	Plant B	Plant C	Plant D
	All ages									
Total	318	48	58	123	89	100.0	100.0	100.0	100.0	100.0
Normal or first degree linear	97	24	11	34	28	30.5	50.0	19.0	27.6	31.5
Second degree linear	184	24	38	74	48	57.9	50.0	65.5	60.2	53.9
First and second degree granular	35	0	9	14	12	11.0	0	15.5	11.4	13.5
Nodular or conglomerate	2	0	0	1	1	.6	0	0	.8	1.1
	Under 40 years									
Total	139	14	23	76	26	100.0	100.0	100.0	100.0	100.0
Normal or first degree linear	63	8	9	28	18	45.3	57.1	39.1	36.8	69.2
Second degree linear	67	6	12	42	7	48.2	42.9	52.2	55.3	26.9
First and second degree granular	9	0	2	6	1	6.5	0	8.7	7.9	3.9
Nodular or conglomerate	0	0	0	0	0	0	0	0	0	0
	40 to 49 years									
Total	81	26	16	14	25	100.0	100.0	100.0	100.0	100.0
Normal or first degree linear	23	14	2	2	5	28.4	53.8	12.5	14.3	20.0
Second degree linear	47	12	12	8	15	58.0	46.2	75.0	57.1	60.0
First and second degree granular	11	0	2	4	5	13.6	0	12.5	28.6	20.0
Nodular or conglomerate	0	0	0	0	0	0	0	0	0	0
	50 years or over									
Total	98	8	19	33	38	100.0	100.0	100.0	100.0	100.0
Normal or first degree linear	11	2	0	4	5	11.2	25.0	0	12.1	13.2
Second degree linear	70	6	14	24	26	71.4	75.0	73.7	72.7	68.4
First and second degree granular	15	0	5	4	6	15.3	0	26.3	12.1	15.8
Nodular or conglomerate	2	0	0	1	1	2.1	0	0	3.1	2.6

Table E.—*Hemoglobin values of male open-hearth workers in 4 steel plants according to plant*

Hemoglobin grams per 100 cubic centimeters of blood	Number					Percent				
	Total	Plant A	Plant B	Plant C	Plant D	Total	Plant A	Plant B	Plant C	Plant D
Total	350	48	63	139	100	100.0	100.0	100.0	100.0	100.0
13	4	0	0	2	2	1.1	0	0	1.4	2.0
14	39	5	3	15	16	11.2	10.4	4.8	10.8	16.0
15	102	16	22	35	29	29.2	33.3	34.9	25.2	29.0
16	117	24	24	45	24	33.4	50.0	38.1	32.4	24.0
17	74	3	14	38	19	21.1	6.3	22.2	27.3	19.0
18	14	0	0	4	10	4.0	0	0	2.9	10.0
Mean	15.7	15.5	15.8	15.8	15.7					
Standard deviation	1.1	0.8	0.8	1.1	1.3					

Table F.—*Red blood count (millions per mm.³) among male open-hearth workers in 4 steel plants according to plant*

Red blood count in millions per mm ³	Number					Percent				
	Total	Plant A	Plant B	Plant C	Plant D	Total	Plant A	Plant B	Plant C	Plant D
Total	350	48	63	139	100	100.0	100.0	100.0	100.0	100.0
4.2	1	0	0	1	0	.3	0	0	.7	0
4.3	1	0	0	1	0	.3	0	0	.7	0
4.4	3	0	1	1	1	.9	0	1.6	.7	1.0
4.5	3	0	0	2	1	.9	0	0	1.4	1.0
4.6	8	1	0	4	3	2.3	2.1	0	2.9	3.0
4.7	24	3	2	7	12	6.9	6.2	3.2	5.0	12.0
4.8	59	6	12	23	18	16.8	12.5	19.0	16.6	18.0
4.9	58	7	11	24	16	16.6	14.6	17.5	17.3	16.0
5.0	80	12	12	34	22	22.8	25.0	19.0	24.5	22.0
5.1	68	6	14	30	18	19.4	12.5	22.2	21.6	18.0
5.2	34	7	9	11	7	9.7	14.6	14.3	7.9	7.0
5.3	8	4	2	1	1	2.3	8.3	3.2	.7	1.0
5.4	3	2	0	0	1	.8	4.2	0	0	1.0
Mean (millions/mm ³)	5.0	5.0	5.0	4.9	4.9	------	------	------	------	------

Table G.—*Distribution of total leucocyte count among male open-hearth workers in 4 steel plants according to plant*

Total leucocyte count per mm ³	Number					Percent				
	Total	Plant A	Plant B	Plant C	Plant D	Total	Plant A	Plant B	Plant C	Plant D
Total	350	48	63	139	100	100.0	100.0	100.0	100.0	100.0
Less than 5,000	1	1	0	0	0	0.3	2.1	0	0	0
5,000	12	3	0	4	5	3.4	6.2	0	2.9	5.0
5,500	5	1	1	2	1	1.4	2.1	1.6	1.4	1.0
6,000	34	6	0	22	6	9.7	12.5	0	15.8	6.0
6,500	15	0	4	5	6	4.3	0	6.4	3.6	6.0
7,000	35	2	4	16	13	10.0	4.2	6.4	11.5	13.0
7,500	16	5	4	4	3	4.6	10.4	6.3	2.9	3.0
8,000	52	7	5	28	12	14.9	14.6	7.9	20.2	12.0
8,500	31	4	13	7	7	8.9	8.3	20.6	5.0	7.0
9,000	32	6	3	15	8	9.1	12.5	4.8	10.8	8.0
9,500	15	0	6	4	5	4.3	0	9.5	2.9	5.0
10,000	25	4	4	11	6	7.1	8.3	6.3	7.9	6.0
10,500	14	1	4	3	6	4.0	2.1	6.3	2.2	6.0
11,000	31	6	10	5	10	8.9	12.5	15.9	3.6	10.0
11,500	11	1	2	4	4	3.1	2.1	3.2	2.9	4.0
12,000	7	1	0	3	3	2.0	2.1	0	2.2	3.0
12,500	6	0	3	2	1	1.7	0	4.8	1.4	1.0
13,000	3	0	0	1	2	.8	0	0	.7	2.0
13,500	2	0	0	2	0	.6	0	0	1.4	0
14,000	2	0	0	1	1	.6	0	0	.7	1.0
14,500	0	0	0	0	0	0	0	0	0	0
15,000	1	0	0	0	1	.3	0	0	0	1.0
Mean	8,825	8,510	9,400	8,535	9,015	------	------	------	------	------
Standard deviation	2,000	1,940	1,650	2,000	2,165	------	------	------	------	------

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